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ROOF CARPENTRY

PRACTICAL LESSONS
IN
THE FRAMING OF WOOD ROOFS

FOR THE USE OF WORKING CARPENTERS

BY
GEORGE COLLINGS
AUTHOR OF "CIRCULAR WORK IN CARPENTRY AND JOINERY," "A PRACTICAL TREATISE ON HANDRAILING AND STAIRBUILDING"

Illustrated with Numerous Diagrams

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PREFACE.

The following lessons in the framing of Wood Roofs of almost every description will, it is believed, be found thoroughly practical throughout, the Author not having attempted to deal with the theory of his subject. Although he believes the mechanical principles underlying the practical lessons of this little volume not to be beyond the capabilities of a workman of ordinary intelligence, yet the study of them presents so many initial difficulties, and requires such close reasoning and application, as to render it wholly uninviting and uninteresting to workmen in general.

The application of the rules given for finding the dimensions of roof timbers is explained very fully, one example of each rule being worked out, and each distinct operation in the process being shown. Further, to obviate the tediousness of stopping to find the various roots required, Tables of Square and Cube Roots have been given from one up to ten inches, including half-inches. This is believed to be an entirely new feature in a work of this description; and the Author hopes that it may prove useful and acceptable to all who make use of the volume.

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INTRODUCTION.

PERHAPS in no part of the operation of building a house is the practical skill of the carpenter called more into exercise than in putting on the roof. Even with the most simple form of roof there is opportunity for the display of the workman's ability in several ways—such as getting out proper moulds, finding correct bevels, use of tools, especially the hand-saw, and so forth.

In the more complicated forms the same opportunity is presented for the satisfactory display of practical ability, but on a largely extended scale; while in most cases of any importance very nice and scientific calculations are needed for ascertaining the strength of various beams and frames and their capability of resisting the strains to which they may be subjected; also for determining the correct sizes of the various timbers composing the roof.

The latter only of these calculations will be considered in this treatise. If any reader desires to enter more fully into the study of theoretical Carpentry in its relation to roofing, he will find the subject fully treated of in Tredgold and Tarn's "Carpentry and Joinery," with an Atlas of Plates in illustration.

In carrying out the operation of erecting a house or other building, the calculations for determining the sizes of the timbers are made by the person designing the roof as an invariable rule, and rightly so. There is no reason, however, why the workman engaged in constructing the roof should not become acquainted with and understand the rules and formulæ used for this purpose, so as to be able to use them himself should occasion require it.

These rules and formulæ are usually expressed in an algebraical form, letters being used instead of figures or words. This renders them wholly unintelligible at times to any one not acquainted with algebra.

It need not be so, however, and we hope to be able to show in the following pages—so far as these formulæ are used for the purpose of determining the sizes of roof timbers—that they can

be worked out, and their apparent difficulties solved, by any one having a fair ordinary knowledge of arithmetic, especially if it be accompanied by a good practical knowledge of the subject under consideration.

In order to keep each branch of the subject separate and distinct from every other, we shall present our remarks in the form of chapters, in the following order:—

I. Forms of Roofs.

II. Pitch of Roofs and their Coverings.

III. Details of Different Kinds of Roofs. (Including particulars as to strains, shoulders, abutments, straps and bolts, lengthening tie-beams, purlins, &c).

IV. Rules for finding the Scantlings of Roof Timbers.

V. Roofs of Special Construction.

VI. Roofs of Wood and Iron.

VII. Hip Roofs. (Including rules for finding the bevels of purlins, and lengths and bevels of common jack and hip rafters, &c).

ROOF CARPENTRY.

CHAPTER I.

FORMS OF ROOFS.

THE forms of roofs are very varied. They differ, of course, according to the plan of the building to be covered in, and they may differ also on buildings having the same plan.

Thus, a building with a square or rectangular plan may be covered in, so far as its size will admit, with a simple lean-to roof of one sloping side; or a span roof, with two sloping sides and a ridge; or four sloping sides and four hips; or eight sloping sides, with four valleys, two ridges, and four gables; or four sloping sides, with four sloping ridges or hips, and four gable ends. Each of these forms will be illustrated presently.

The most simple form is the lean-to or single slope. In this, the wall of one side of the

building is carried up as much higher than the opposite one as may be necessary to obtain the requisite fall for the water to run off as quickly as possible.

In Fig. 1, A shows the plan, and B the end elevation, of a building covered in with a roof of this description. A plate is built into the higher wall, or is made to rest on a projecting corbel course, for supporting the upper ends of the rafters. This form is sometimes called a shed roof, although it is no more entitled to such a distinctive appellation than the form shown in the next figure.

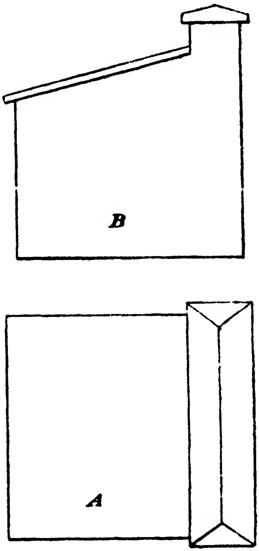

Fig 1.

In Fig. 2, A shows a plan, and B an end elevation, of a span roof, the slopes of each side being inclined at the same angle. The meeting of the sides at their highest point is called the ridge, and the triangular space at each of the wall ends, above the eaves line, the gable.

It may be, however, that the building is in

a very exposed situation, in which case gable ends are not always desirable, and this form of roof may not be considered the best for keeping out the wet. It may then be covered with a roof like that shown in Fig. 3, which is called a hip or pavilion roof. The slopes in a roof of this description on all four sides are equal, and inclined at the same angle to the horizon. The sloping angular lines, or *arrisses*, which result from the intersections of the sides of the roof, are the hips of which the lines BC, BD, AE, and AF are the plans, AB being the plan of the ridge.

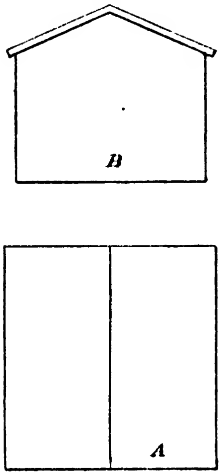

Fig 2.

This is a more expensive form of roof than that shown in Fig. 2, but in exposed situations it is often considered advisable to employ it. It has a much more neat

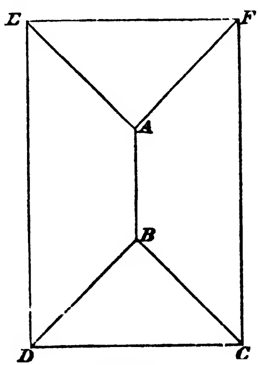

Fig 3.

and compact appearance than gable ends and a span roof, and when the work is properly and efficiently done it will make a good sound covering for the building.

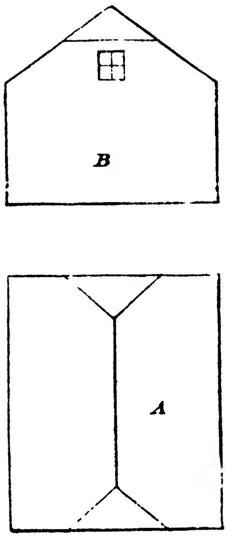

Fig 4.

Sometimes the room inside the roof is utilised for attics, and in order to get as much room as possible, and introduce a window without resorting to the expensive and often troublesome dormer in the sloping sides, the ends are hipped off at the required height above the eaves level, as shown in Fig. 4, A being the plan and B an end elevation. It is then called a truncated hipped roof or jerkin head.

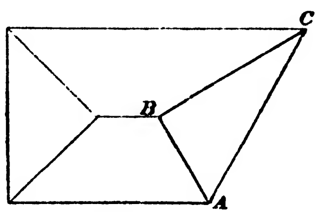

Fig 5.

When the ends of the building are at right angles to its sides, as in Fig. 3, the hips are called right hips; but if the angles are unequal, as at A, B, C, Fig. 5, it is called an oblique or skewed hip.

The angles at A and C should, however, be bisected by the hip, the same as in a right-angled building.

It not unfrequently happens that the building to be roofed in is wider at one end than the other, and in order to get the two longest opposite sides true and out of winding, it becomes necessary to introduce a V flat on the top. This is shown at ABCA, Fig 6, each of the lines AB and AC being drawn parallel to the sides DE and FG respectively, and meeting the seat line of the oblique hips in B and C. The pitch of the roof being determined, the mould for the common rafter may be obtained by drawing its seat line at right angles to either DE or FG, as at HJ.

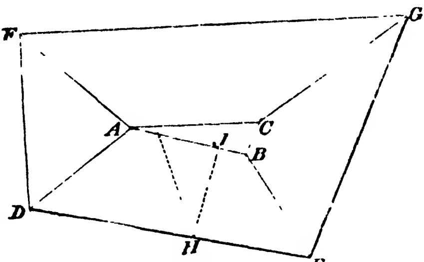

Fig 6.

Then if JA is made equal to the rise or pitch of the roof, AH will be the length along the back of the common rafter. This will be considered more fully in future pages.

Other methods of covering in an irregular plan similar to that shown in Fig. 6, are also adopted

as situation, size of building, and so forth, may require. But where one span is sufficient, the above form can be made a very compact and efficient covering.

A square building, as before observed, may be roofed in in several different ways.

It may have a span roof and two gables, as in

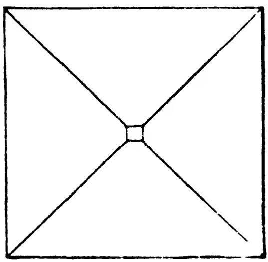

Fig 7.

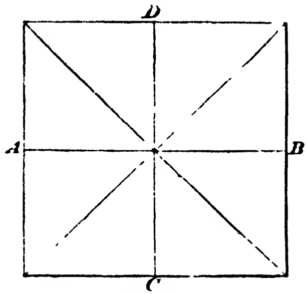

Fig 8.

Fig. 2, or a hipped roof, as shown in plan, Fig. 7, the apex being not unfrequently ornamented with a turned finial, into the lower end of which the hips are framed, and a weather vane on the upper end, or a valley roof with four valleys, eight sloping sides, and four gables, as shown in plan at Fig. 8, AB and CD

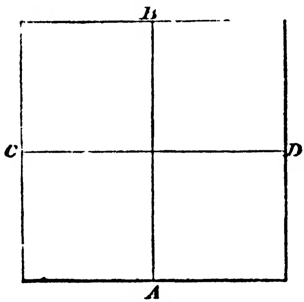

Fig 9.

being ridges at right angles to each other, and to the sides of the building, and the diagonals showing the seat lines of the valleys. Or a roof may be put on, as shown in Figs. 9 and 10, Fig. 9 being the plan, and Fig. 10 an elevation of any one of its sides. In this roof the seat lines of the hips are not on diagonals to the square, but on the lines AB and CD.

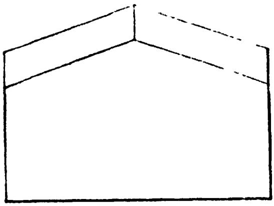

Fig 10.

This last example has four equal and similar gables, and four equal sloping sides.

Valleys are also formed in a roof when two buildings of equal or unequal width cross each other at a right or any other angle.

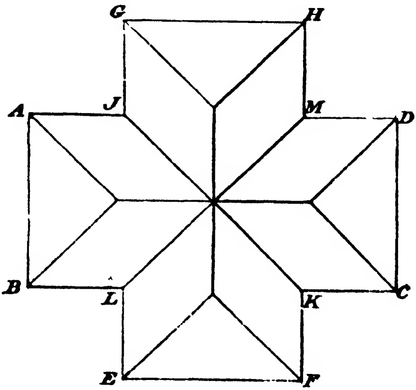

Fig 11.

Thus, in Fig. 11, let ABCD, EFGH be two

ranges of buildings of equal width, and crossing each other at right angles; then the diagonals JK, LM will be the centre seat lines of the valleys. The ends of each range, instead of being gabled, are sometimes hipped, as shown in the figure.

When one of the buildings is wider than the other, and the slopes of each are inclined at the same angle to the horizon, and the eaves are all on

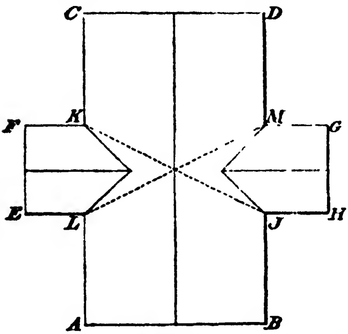

Fig 12

the same level, the ridge of the wider range will be higher than that of the narrower one Thus, in Fig. 12, let ABCD be the wide range, and EFGH the narrow one. Then by bisecting the angles we obtain the distance to which the ridge of the narrow building runs into the sloping sides of the wide one.

If instead of the slopes all being the same, the ridges and eaves are required to be of the same vertical height, then the sloping sides of the narrow building will require to be much steeper than those of the wide one, and the centre seat lines of the valleys will be as shown by the dotted lines JK, LM.

Or the ridges may be kept to the same vertical height, and the slopes to the same inclination by having the eaves of the narrow range higher than those of the wide one, as shown in plan at Fig. 13.

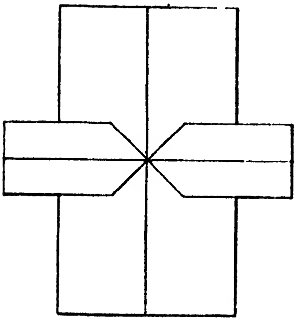

Fig 13.

If a wide building intersects a narrow one at any angle, and the slopes of the roof in each are the same, the sides of the wide one will intersect with the narrow in a valley part of the distance and the remainder will be a hip.

Thus in Fig. 14, let AB be the wide, and CD the narrow range.

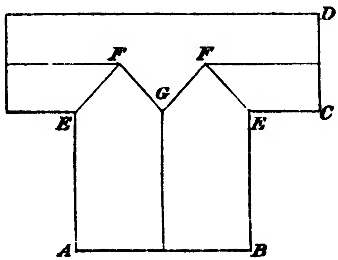

Fig 14

Then EF will each be valleys, and FG will each be hips.

Sometimes a narrow building projects beyond the end or side of a much wider one, both of them having a span roof of equal slope, and eaves at the same level.

The intersections of the sloping end of the wide with the sloping side of the narrow, will then form a valley as at AB, and a hip, BC, Fig. 15.

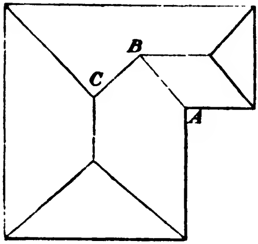

Fig 15.

If two buildings of equal — or it may be unequal—width cross each other at an oblique angle, as in Fig. 16, four valleys will be formed, two long and two short, AB being the centre seat lines of the long ones, and CD the centre seat lines of the short ones. Each angle is bisected and divided into two equal parts by drawing the straight lines AB and CD, as shown in the figure, thus obtaining the centre seat lines of the valleys as required.

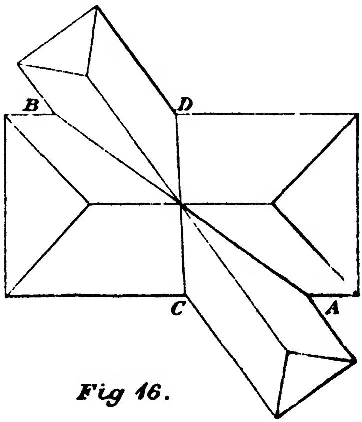

Fig 16.

In the next example, Fig. 17, the intersection of the sloping sides of the roof form valleys on the interior, and hips on the exterior. By draw-

ing straight lines from the intersections, as at AB and CD, we obtain the centre seat lines of the hips and valleys, and the angles are properly bisected and divided into equal and similar parts.

Hips and valleys are said to be regular and irregular, or equal and unequal. Hips will be regular and equal when the end of the building is

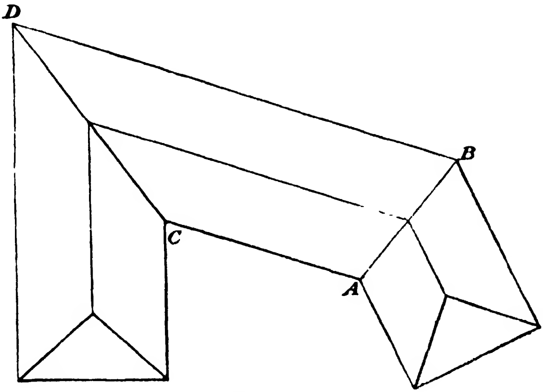

Fig 17.

at right angles to its sides, and the slopes of the roof are the same, as in Fig. 11, but they become irregular and unequal when the end of the building is not at right angles to its sides, as at E and G, Fig. 6.

Valleys are regular and equal when the buildings crossing or meeting each other are at right angles, and the width and slope of roof are the

same as at JK, LM, Fig 11, but they become unequal when the buildings are not at right angles, as at AB, CD, Fig. 16.

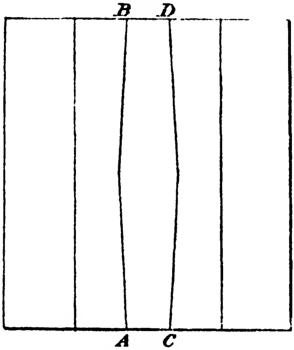

Fig 18

When the building is a wide one, and it is considered advisable to keep the roof low, it may be and often is effected by dividing the span into two, and making the roof to consist of four principal slopes, two external and two internal. This form of roof somewhat resembles the letter M, and from this fact it is called an M roof.

Fig. 18 shows the plan, and Fig. 19 an end elevation, of such a roof with gables. At the meeting of the internal slopes a gutter is formed for carrying away the water. This is shown in Fig. 18, by the diverging lines AB, CD, the widest and highest part of the gutter being in the middle, and gradually falling and diminishing in width from this point to

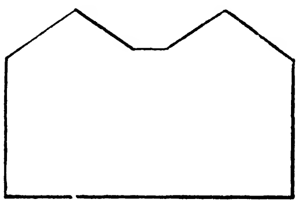

Fig 19

each outside, so as to convey the water away to each end. In a very long building intermediate outlets for the water have sometimes to be provided. The falls then would consist of four or six as required, instead of two as shown in the figure. Two, however, may be made to do for a tolerably long building, if the necessary drips are introduced between the centre and each end of the gutter.

The above form of gutter, though a somewhat expensive one if properly done, is necessary in large buildings where a large quantity of water has at times to be conveyed away by it. It is also the best for the occasional repairs required to the roof, as it gives plenty of room for moving about, without being obliged to tread upon the slates so much as when there is only a trough or sunk gutter. The latter is used in smaller structures where the roof space is comparatively small, and where the quantity of water is not likely to be very considerable.

It is made of a parallel width of about 6 ins.—more or less as circumstances require—and with the necessary falls and depth, so as to convey the water away as rapidly as possible.

Fig. 20 exhibits the plan of a span roof on a circular building, and hipped at both ends. The rafters and hips for a roof of this description will

require to be straight, but the ridge, plates, and purlins, when the latter are required, must be cut out of the solid to their respective curves in suitable and as long lengths as possible.

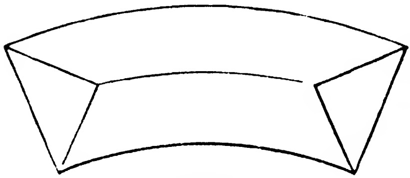

Fig 20

The sides of the purlin should be vertical, as at AA, Fig. 21. If they are placed at right angles to the slope of the rafter, they will become of double curvature, and there will be a difficulty and waste of material in cutting them out.

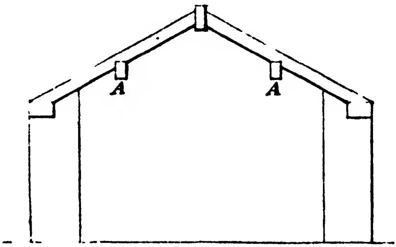

Fig 21.

Roofs of square and polygonal plans with curved ribs or rafters, also domical roofs, are fully treated of and described in the author's treatise on "Circular Work in Carpentry and Joinery,"* and will not be considered in this.

Fig. 22 is the plan, and Fig. 23 an elevation, of

* The Technical Press Ltd.

a pentagonal roof. The centre seat lines of the hips A, A, A, bisect and divide each of the angles

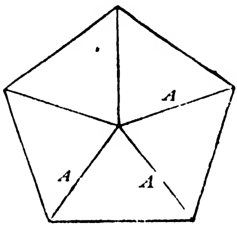

Fig 22

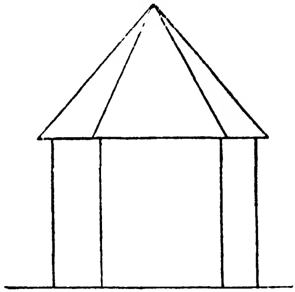

Fig 23.

into two equal and similar parts. The apex in the elevation, Fig. 23, may be finished with a

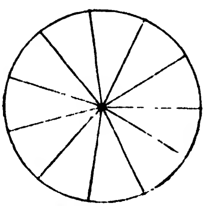

Fig 24.

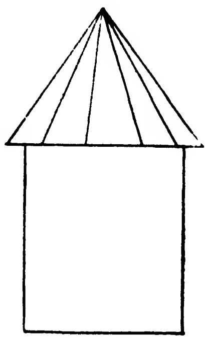

Fig 25.

turned finial and weather vane, or the roof may be truncated and have a lead flat for the top.

A hexagonal or octagonal plan would be treated

similarly to the last (Fig. 22). The centre seat lines of the hips should bisect and divide the angles as in that figure.

Fig. 24 is the plan, and Fig. 25 the elevation of a conical roof of steep pitch.

This form of roof, with a method of finding its covering, is fully described in the before-mentioned "Circular Work."

Perhaps, however, the best method of covering this roof is to put the boards on lengthways from the eaves to the apex, tapering them as required, and employing a sufficient number of horizontal rings for nailing the boards to. The diameters of the rings are easily ascertained from their position in the elevation.

CHAPTER II.

PITCH OF ROOFS AND THEIR COVERINGS.

By the pitch of a roof is meant the inclination or slope of the sides. It is described by the number of degrees contained in the angle of inclination to the horizon, or more commonly perhaps by the proportion which the height, measured from the springing line* to the apex, bears to the span. Thus, if a building is 20 ft. wide outside the walls, and the roof is to have a quarter pitch, the height from the top of the plates, when they are laid flush with the outside of the walls, and the back of the common rafters are flush with the upper outside arris of the plate, to the apex or meeting point of the rafters at the ridge, should be 5 ft., as shown in Fig. 26.

This would be an angle of inclination to the

* The springing line of a roof is a straight line drawn through the points of intersection of the vertical outside face of the building with the back of the common rafter (as at AB, Figs. 26, 27, and 28).

horizon of 26½°. If the slope is to form an angle of 45° with the horizon, the height, measured as above, should be half the width of the building, and the angle at the apex of the roof would be a right angle. From this fact this slope is sometimes called a square pitch.

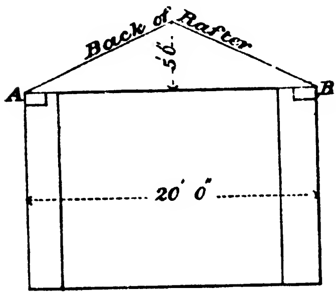

Fig 26.

If the roof has overhanging eaves and the lower ends of the rafters, instead of finishing as shown in Fig. 26, are cut as shown in Fig. 27, then the springing line will be at AB, and not at the top of the plate.

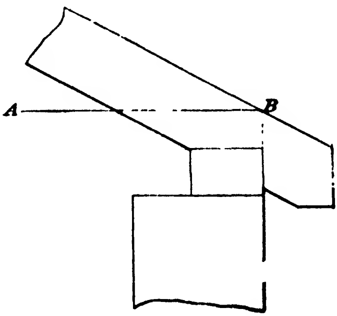

Fig 27.

Figs. 26 and 27 show the plate laid fair with the outside of the wall. A more usual and better place is fair with the inside and sometimes on the middle. When, however, the plate is laid anywhere except flush with the outer

face of the walls, and the rafters are cut differently than as shown in Fig. 26, then the pitch for the roof should be measured from the point where the back of the rafter is cut by the outer face line of the wall, as at AB, Fig. 27.

This is further exemplified in Fig. 28, where the plate is shown to lie fair with the inside of the wall, the line AB being the springing line as before. The same dimensions being used in this last figure as in Fig. 26, the meaning will be at once evident.

The slope of any required pitch for a roof may thus be laid down easily and accurately, by making the height equal to the required proportion of the width of the building as shown in Figs. 26, 27, and 28.

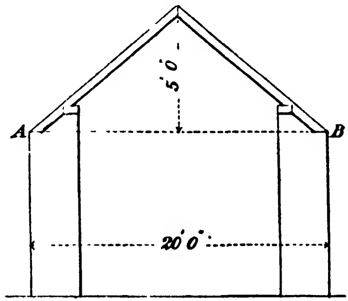

Fig 28.

A protractor may be used for the same purpose, as shown in Fig. 29.

Thus:—place the straight edge of the protractor at right angles, and its centre to the vertical face lines of the wall, and prick off the required number of degrees on its semicircular

edge. Then through the latter point and the centre of the protractor draw the line for the pitch of the roof, which line will also be the back or uppermost edge of the common rafter.

The pitch required will of course depend upon the material to be used for covering the roof. For a covering such as thatch the slope should be very steep. The angle of inclination usually given for this is 45°.

So far, however, as a good many existing examples may be taken as a guide, it should be steeper than this, probably not less than from 50° to 55°. Be this as it may, the steeper the roof is made within reason for such a covering the better, both for keeping out the wet and making the material last as long as possible.

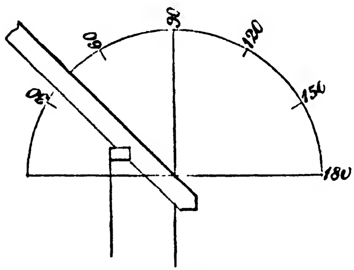

Fig 29.

Roofing felt is a material largely used for temporary buildings, such as sheds and similar structures, in which the pitch is made very low. But its capability of keeping out the wet is constantly being renewed by fresh coats of tar so

that there is no need for the pitch to be at all a sharp one.

So far as buildings of a permanent character are concerned, the materials most largely used for covering them in, in this country, are slates and tiles, and of these two slates by far the most largely. Other materials, such as copper, sheet iron, corrugated iron, lead, zinc, slabs of stone, &c., are used only occasionally and in exceptional circumstances, and will not be considered in this treatise any further than the particulars in reference to them, which are given in the table on page 23. With a covering material of slates or tiles, the pitch of the roof is varied considerably, so as to suit different styles of architecture and different climates, it being made steeper in cold and exposed situations than in warm and less exposed ones.

But although slates are so largely used, and though they undoubtedly make a thoroughly good and durable covering, they are not the most suitable or comfortable for dwelling-houses and workshops, unless proper provision is made for preventing, as far as possible, the extremes of heat and cold to which they give rise.

Workmen sometimes experience these extremes in a most intense form while employed in work-

shops with a low pitched roof covered with slates which are laid on battens only. To obviate these inconveniences, and prevent as far as possible the uncomfortable effects produced by the slates being simply laid upon and fastened to battens only, the roof should be boarded, then covered with felt, and if battens are then nailed on the top of these for receiving the slates, so much the better.

For ordinary dwelling-houses and buildings of a similar description, the pitch varies only, as a rule, from one-fourth to one-third of the width when the covering material is slate. When tiles are used for the same class of buildings the pitch should be from one-third to one-half the width, the latter being considered the best and most desirable in exposed situations.

The following table is from Rivington's "Notes on Building Construction." As will be seen, it gives the inclination or slope for roofs that are covered with different materials, and also the weight per square of 100 ft. superficial of the materials used. The latter, of course, may vary considerably according to their quality and thickness:—

Kind of Covering.	Inclination of sides of roof to horizon.		Height of roof in parts of span.	Weight on a square (*i.e.* 100 sq. ft.) of roofing.
	deg.	min.		lbs.
Asphalted felt	3	50	$\frac{1}{30}$	30—40
Copper	3	50	$\frac{1}{30}$	80—120
Corrugated iron, 16 B.W.G *	4	0	$\frac{1}{29}$	350
Sheet iron, 16 B.W.G. . .	18° to 20°		$\frac{1}{6}$	250
Lead	3	50	$\frac{1}{30}$	550—850
Slates, large	22	0	$\frac{1}{5}$	900—1,100
Ditto, ordinary	26	30	$\frac{1}{4}$	550—800
Ditto, small	30	0	$\frac{1}{3}$	450—650
Slabs of stone	39	0	$\frac{2}{7}$	2,380
Thatch, straw	45	0	$\frac{1}{2}$	650
Tiles, plain	39	0	$\frac{2}{7}$	1,800
Ditto, pan	24	0	$\frac{2}{9}$	1,200
Ditto, Taylor's Patent . .	30	0	$\frac{1}{3}$	830
Zinc, $\frac{1}{32}$ in. thick	4	0	$\frac{1}{29}$	150
Boarding, $\frac{3}{4}$ in. thick . .	26	30	$\frac{1}{4}$	250
Ditto, 1 in. thick	26	30	$\frac{1}{4}$	350

N.B. The additional pressures to be taken into account in practice are the following:—

Pressure of wind, 2,500 to 5,000 lbs. per square of 100 ft.

Pressure of snow, 500 lbs. per square.

* B.W.G. stands for Birmingham Wire Gauge, a measure of thickness

CHAPTER III.

DETAILS OF DIFFERENT KINDS OF ROOFS.

The following are the particular kinds of roofs of which details will now be given :—The flat roof or lead flat; the lean-to or shed roof; the couple or span roof; the collar-beam roof; the collar and tie beam roof; the king-post truss and roof; the queen-post truss and roof.

The Flat Roof or Lead Flat.—This kind of roof when it forms the entire covering for a building is confined to very small spans as a rule, and is used only occasionally and in exceptional circumstances.

It is sometimes introduced in the form of a V flat at the upper part of a slated or tiled roof covering in a building which is wider at one end than at the other, as shown in Fig. 6. It is also sometimes introduced at the upper parts of similarly covered roofs to keep them as low as possible,

thus forming a truncated hip roof, which will be described hereafter.

The fall is made only just sufficient for the water to run off, 1 inch in 10 feet being the least it should have. Snow will lie on it until melted, if not previously removed by hand. The covering material is usually sheet lead, sometimes zinc, and occasionally copper.

Instructions as to falls, drips, rolls, &c., are considered to fall within the province of the plumber, and to him the carpenter invariably looks in matters of this description before doing the work.

The Lean-to or Shed Roof.—This kind of roof has been previously spoken of (see description of Fig. 1). As there stated, one side of the building to be covered in is carried up as much higher than the other as may be necessary to obtain the requisite fall, which in most cases for roofs of this kind need not be a very sharp one, the building frequently being erected for temporary purposes only, and the covering material felt, the surface of which is constantly being renewed by fresh coats of tar and sand, tar and lime, or tar and cement to make it waterproof.

When the building is of a permanent character, and the covering material slates or tiles, the slope

should be made to the required pitch for whichever of those materials is used, if it be possible to do so consistently with safety to the higher side.

When the slope cannot be thus adjusted, the flatness of the roof should be compensated for by an increased lap in the slates or tiles to ensure keeping out the wet. If the lean-to is against another building and that building is sufficiently strong to bear the weight of the lean-to constantly pressing against it, the pitch may be made as required for either slates or tiles. But if, as is often the case, the lean-to is against a wall carried up for the purpose, and to form one side of the building, the pitch must not be so high as to jeopardise the safety of the wall so leaned against.

The higher the pitch of the roof the greater will be the thrust of its weight in the direction of tending to push the wall over, while with a flat roof the thrust will be more in a perpendicular direction.

The matter perhaps is not of any very great importance for this class of roof, but it will be easily perceived from Fig. 30 that the thrust of the roof against the higher wall will be much greater if the slope is made as at AD than if made as at AC.

These remarks, in great part at least, are not intended to apply to a number of town houses,

which are covered in with a roof very similar to that we are describing, namely, a double lean-to, the two slopes, with a trough gutter between them, forming the entire roof for a single tenement. Numbers of these small houses are built in rows, the partition wall between each being carried up high enough to take the bearing of two opposite slopes.

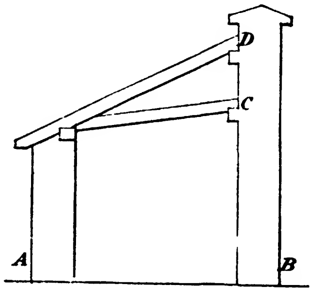

Fig 30.

Fig. 31 is a sketch of such a roof.

The feet of the rafters rest on the pieces which form the sides of the gutter, and the upper ends

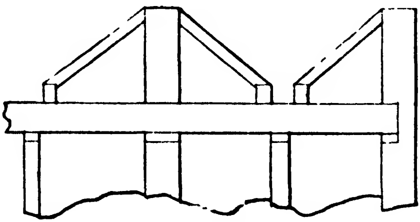
Fig 31.

are usually birdsmouthed on to a plate built in the wall.

A projecting course or two of brick, as at C Fig. 30, for supporting the plate, is much better

than building it in the wall as, when so built in, the upper ends of the rafters have to be built in also, with the result that if the damp gets into the wall both plate and rafters soon become decayed, and the roof so far destroyed. The plate may be easily tied to the wall by pieces of hoop iron, which should be nailed to the plate and built in the wall as the work is carried up.

The particulars necessary to be known preparatory to setting out a roof of this kind will be the width as from A to B, and the height of the plate at C above that on the lower wall, A, Fig. 30. Having these dimensions, the roof may be set out, and a mould for the rafters readily obtained. The number required may then be cut out, and the whole of the materials be got ready before taking them to the building if necessary.

At the feet of the rafters a tapered piece, called a *tilting fillet* or *eaves lath*, is fixed all along the eaves to give the first course of slates or tiles the required tilt, so as to make room for the upper ends of the under-eaves,* and so that the tails of each succeeding course may take a solid bearing on the whole of the part covered of the course immediately underneath, and so that the slates may be fixed without being bent or strained. This will ensure close-fitting joints along the lower ends of

* The eaves in slating and tiling are laid double, the under course or under-eaves being a little more than half the entire slate or tile (see Fig. 32).

all the courses, and will leave no space for the wind to drive the rain up under them or strip them off.

The tilt usually given is about ½ in., the thickness of the upper edge of the tilting fillet being the same as the boarding or battens. See Fig. 32, which is purposely exaggerated, and shows the slates laid on battens.

They are laid the same if boarding be used instead of battens.

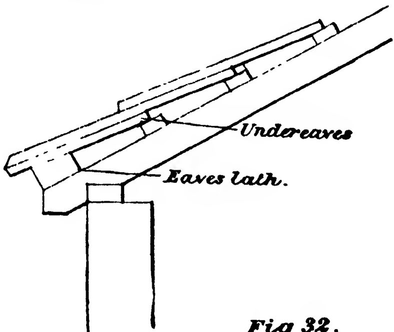

Fig 32.

Methods of Laying and Finishing the Eaves of Roofs Generally.—The above method of laying the slates or tiles at the eaves is not confined to the foregoing kind of roof. They are laid in the same way generally with all roofs, whether of flat or steep pitch. A similar tilt is given to the first course of slates or tiles by the sides of gutters and valleys, and for the same reason as stated above. The boards for the sides of the gutters are carried the required distance up the rafters,

and a tilting fillet, like that shown at AA, Fig. 33, is nailed at the proper place on this board. The fillet is usually about 2 ins. wide and ⅜ in. on the thick edge. The same tilt is given to the slating by the sides of chimneys and brick walls by using a fillet similar to those shown in Fig. 33. The reason for the tilt in the latter case, however, is not the same as for that at the eaves,

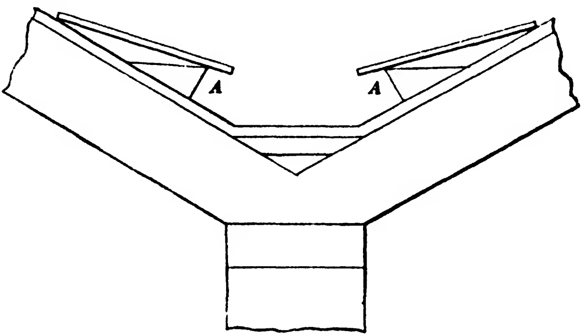

Fig 33.

but simply that the water may the more readily run away from the brickwork.

The thickness of the tilting fillet for slating at the eaves should in reality vary, so as to suit different lengths of slates, a short one requiring a thicker fillet than a long one. Thus, a tilting fillet that would be suitable for a small slate called a "single," and measuring 12 ins. by 8 ins., would be found nearly double the thickness required for

one called a "queen," and measuring 36 ins. by 24 ins., the thickness of each slate being the same, and so on in proportion for other sizes.

If the tilting fillet is too thick the slates will lie hollow, and will be very liable to get broken as soon as any pressure is put upon them. If it is too thin the slates will ride in the middle on the upper ends of those immediately underneath them, and will have a similar liability to get broken as before, with the addition of a space along the lower ends of the courses for the wind and rain to drive up under them. Of the two evils, therefore, the former should be preferred.

The exact thickness, however, required for any length of slate may easily be ascertained when the gauge is known. Suppose the slates to be used are duchess, measuring 24 ins. by 12 ins., and that they are to have a lap of 3 ins., this would give a 10½-in. gauge, and consequently each course of slates would go 10½ ins. up the roof beyond the one underneath it.

Then to find the tilt for the eaves, take two slates, the thickest ones always being used for the lower courses, and lay one of them flatways against a straight edge and the other one on it, in the same way as they are laid on the roof, *i.e.* with the end of the last slate projecting 10½ ins beyond the first and brought down close to the

straight edge on which the first slate is laid, and the distance or space between the slates at the lower end of the second will give the required thickness of the tilting fillet for the eaves.

Thus in Fig 34, let the line AB be the straight edge and C the first slate laid against it as directed, and let DE be the second slate laid close to the

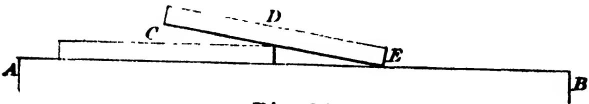

Fig 34.

under one at D, and the end E close to the straight edge AB. Then the space between the slates at C will be the thickness required for the tilting fillet.

The eaves of roofs, not necessarily such as the foregoing, are finished with a soffit and facia. The tilting fillet may then be dispensed with by keeping the top edge of the facia the required distance above the boarding or battens on which the slates are laid. When the eaves project very much the soffit is sometimes plastered, the laths for which are nailed to horizontal bearers which are let into the wall at one end and nailed to the rafter foot at the other. And sometimes match-boarding is used in preference to plaster.

Fig. 35 shows the projecting eaves of a roof with soffit and facia. The facia should be wide

enough for fixing the gutter and obtaining the

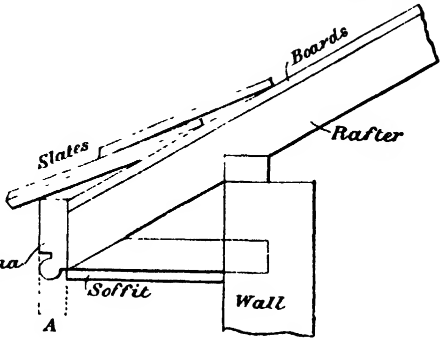

Fig 35.

necessary falls for same without covering any part of the return bead at its lower edge. When greater width of the facia is required for the gutter than can be obtained by beading its lower edge, it is made to project below the soffit with a square edge, as shown at A.

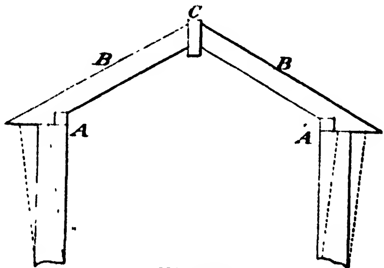

Fig 36.

The Couple or Span Roof.—This kind of roof consists properly of the plates AA, the rafters BB, and the ridge C, Fig. 36, with the addition of the

eaves, lath, and battens, or boarding, which are not shown in the sketch. The particulars necessary to be known for making a working drawing of the same are the outside width of the buildings, the rise or pitch of the roof, and the size of rafters, plates, and ridge. Knowing these, the roof may be set out to scale or full size. The bevels, length of rafters, and quantity of materials may all be obtained from a drawing made to scale. The mould for the rafters can only be obtained by setting it out full size. Having obtained this, the number required may be cut out anywhere and taken to the building ready to fix.

A very usual size for the plates in a roof of this span is 4 ins. or 4½ ins. by 3 ins., and for the ridge from 6 ins. by 1½ ins. upwards. This kind of roof is suited only for small spans and short buildings, except where intermediate ties for the plates are practicable. Some authorities state that it may be used for spans up to 12 ft., without saying anything as to the length. This, however, will affect the span considerably up to which such a roof may be used with safety. If the building is a moderately long one, only, say from 15 to 20 feet, and there are no cross partition walls, the weight of the roof will increase the natural tendency of the rafters to spread at their feet, with the consequence

that the walls will be thrust over as shown by the dotted lines.

If the building has cross partitions, so that the walls may be kept to the perpendicular, and there are no means of tying-in the plates, the rafters will still spread and thrust the plates further apart by causing them to slide on the top of the walls. If, therefore, this kind of roof is used for spans as wide as 10 or 12 ft., it should only be for short buildings, say about 10 feet (unless intermediate ties for the plates are practicable), and even then the plates should be well secured at their ends.

Collar-beam roofs.—The roof just described may be much improved and strengthened for spans up to about 16 feet, by introducing a piece termed a collar, as at AB, Fig. 37. The place for this is usually about half-way up the rafters. If the span is anything over 10 or 12 ft., one should be used to every pair of rafters, and if under that one to every second, third, or fourth pair as may be considered most desirable, and according to the strength of the rafters and plate, a wide plate being much stronger and better able to resist the thrust of the rafters than a narrow one when its ends are well secured.

If the collar is dovetailed into the rafter, as at

AB in the figure, it should not be let in too far, as the farther it is so let in the more the rafter is weakened. A rafter 4 ins. by 2 ins., if notched out half its thickness for the collar, will render it little if any at all stronger than one 4 ins. by 1 in., There is scarcely ever any need to halve rafter and collar so that they are made flush on one or both sides, for if they are not hidden by plaster

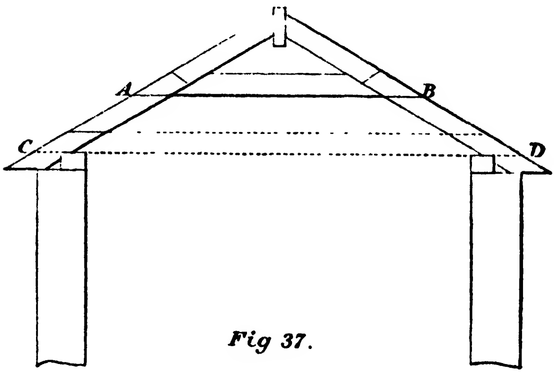

Fig 37.

or match-boarding, the job will be so unimportant as far as appearance is concerned as to render it immaterial whether they are flush or not.

The dovetail joint, however, is not a good one for this situation, and must not be depended upon alone, as the least shrinkage of the timbers allows it to give way and the rafters to spread. Good and careful nailing with good nails is indispensable to make the joint secure.

A better form of joint for this situation than the foregoing is shown in Fig. 38, and if a couple of nails are carefully driven in so as to prevent the piece shearing or splitting off in the direction of the line AB, there will not be much danger of the joint giving way. But even in this case nailing is indispensable so as to hold the two together side by side.

It is said that this kind of roof is bad con-

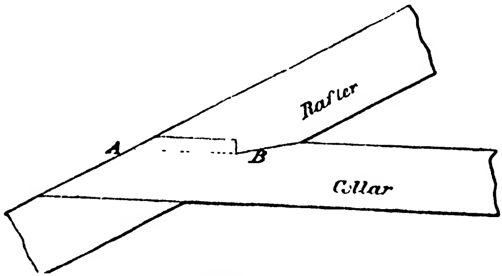

Fig 38

struction, that the rafters are liable to bend from the collar downwards, and that in thus bending they spread at their feet and tend to thrust the walls over. In theory this may possibly be true, but in practice we should say it never is, if the materials are made sufficiently strong and the workmanship is such as it should be. Suppose a building of 14 or 15 ft. span covered with a collar roof like that shown in Fig. 37 (without the tie CD), let the plates be 4½ ins. by 3 ins., rafters and

collars 4½ ins. by 2 ins. and not more than 12 ins. apart, ridge 7 ins. by 1½ ins., and the workmanship of a good sound character, with the rafters and collar put together as directed, and well and securely nailed with good nails, and let the covering materials be of the ordinary description, such as slates.

If these conditions are satisfactorily fulfilled, the stability of such a roof might safely be guaranteed for as long as the materials would be likely to remain sound and good.

For all span roofs of this description collars are advisable and necessary when the roof is more than from 8 to 10 ft. long and there are not means of introducing an intermediate tie for the plate.

Sometimes, however, and when not likely to be in the way, ties are thrown across about every 8 or 10 ft. on the top of the plates, as at CD, Fig. 37.

This position, however, is not a good one for the tie, inasmuch as it must be considerably weakened by cutting off the ends to the slope of the roof. A much better place is as shown in Fig. 39.* But whichever position they are made to occupy, the use of collars as ties will be entirely superseded, and a better job will be the result.

* The plate for the support of the rafters is then called a pole-plate.

If collars are used as well they will then act as struts, and the rafter will be considerably strengthened thereby. But when collars alone are used they act as ties, as will be evident from what has already been said as to their effect in preventing the rafters spreading at their feet.

If the rafters are so long as to require an intermediate support a purlin may be introduced when ties are used, as in Fig. 39, and struts placed on

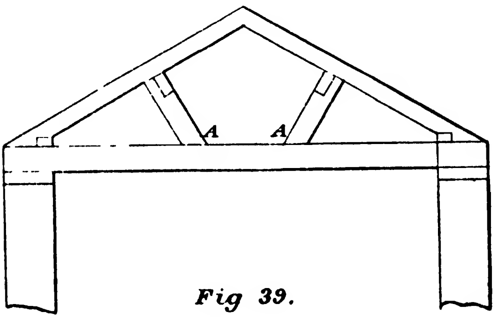

Fig 39.

them to carry the purlins, as at AA. The tie will then require to be about 9 ins. deep, and it should be placed as shown, with stone templates under the ends, and the pole-plate well spiked on to its top edge. An iron dowel inserted into the tie and stone template will be of great service in preventing the spread of the walls.

Another kind of collar-beam roof is frequently used in churches and Gothic buildings of tolerably

wide span, as shown in Fig. 40. The pitch is a very steep one. The collars are placed high up, and framed into the rafters and pinned. Into these, braces, marked BB, are framed and pinned also. The walls, being usually very thick, have two plates, which are framed together with cross-

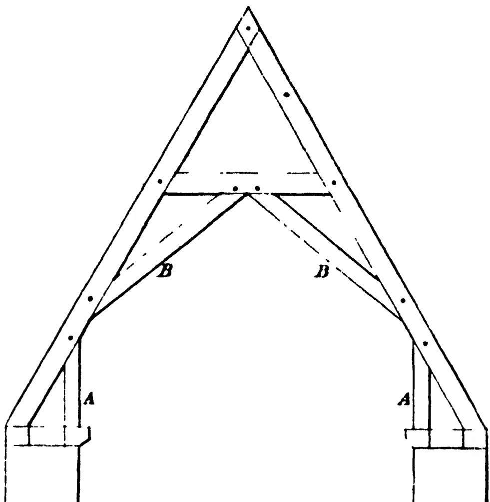

Fig 40.

pieces every 4 or 5 ft. and pinned, the inner one overhanging the wall and having a moulded or chamfered edge.

The struts, marked AA, are tenoned into the plate and rafter at bottom and top, and also pinned. The face of the struts at their lower end are

placed in a line vertically with the face of the wall below the plate. The upper ends are made to fall inwards from about ½ in to 1 in. according to their length, thus framing them out of the perpendicular by so much. By this arrangement they are made to withstand more effectually the downward thrust of the rafters, and the appearance they are apt to present, of falling outwards at top when framed upright, is avoided.

Sometimes the rafters and lower ends of the struts are framed into horizontal cross-pieces, the inner ends of which are cut and shaped ornamentally. The cross-pieces are pinned on to rafter and strut, and notched down into the wall-plates, as shown in Fig. 41, AA being the wall-plates; B the horizontal cross-pieces let into the plates, as shown; C, the strut; and D the lower end of the rafter.

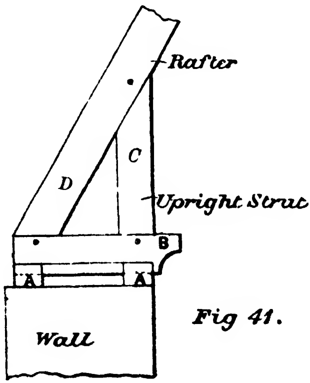

Fig 41.

The foregoing roofs, the details of which we have just been considering, although they may be constructed so as to be very serviceable and effective, are yet limited in their application.

They are suited only for short spans, and are wanting in the strength and stability required to resist the severe strains to which large surfaces of roofing are subject from the weight of the materials they have to carry, the pressure of the wind, and other causes.

The form of roof which is recognised as being the most suitable and effective for spans of from about 18 ft. and upwards, are the king and queen post trusses or framed principals. These may be made sufficiently strong to resist any pressure or strain that is ever likely to be brought to bear upon them. There are several important theoretical considerations connected with these forms, and roofing in general, which will not be entered into in this treatise, except to make a few practical remarks on the different strains to which the timbers in a framed truss or principal are subject. If any reader of these pages should be desirous of studying the theoretical principles of carpentry in relation to roofing, and carpentry in general, he cannot do better than possess himself of one or other of the books refered to in the Introduction (page xii.).

The King-post Truss and Roof, Fig. 42, is an elevation of a king-post truss or principal. Some of the parts are purposely exaggerated.

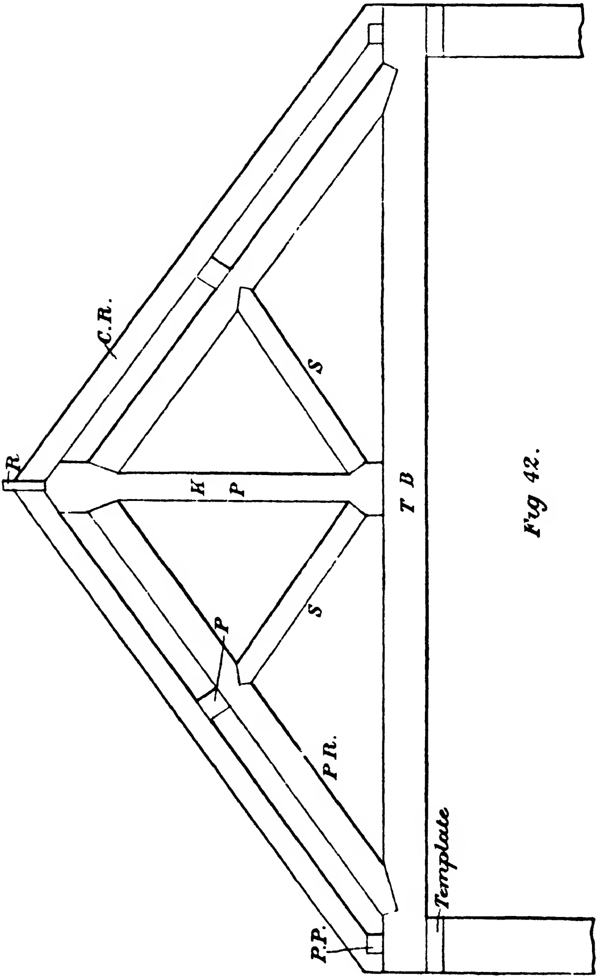

Fig 42.

The names of the parts lettered are as follows:— TB, tie-beam; KP, king-post; PR, principal rafter; S, struts; P, purlins; CR, common rafter; R, ridge; PP, pole-plate, which is placed on the top edge of the tie-beam. The plate or template, whichever may be used, is placed under each end of the tie, and forms a bed for it to rest upon. A stone template of sufficient size makes a good bed for the tie to rest upon, and if an iron dowel is inserted, the walls will be the more effectually tied together.

The better way to proceed in drawing an elevation or section of a roof of this kind, or, indeed, of any roof, is to draw the vertical lines representing the extreme width of the building first. Then set up the pitch according to either of the methods previously given (see description of and Figs. 26 to 29) and let the sloping lines thus produced be the back or uppermost edge of the common rafter. The thickness of the walls and depth of the common rafters may then be laid down, and this will give the place for the pole-plate so far as its height is concerned, whether it is laid inside, outside, or on the middle of the wall. Let the pole-plate be placed so as to get the under edge of the common rafter well on to the top side, leaving about 2 ins. or 2½ ins. in width of the rafter above the outer arris of the plate, as at A, Fig. 43.

(The horizontal, cut in the throating of the rafter, should never be so as to throw its under edge within the plate, as shown at B. This would be reducing the strength of the rafter to no purpose and for no reason.) The under side of the pole-plate (Fig. 42) will now give the position for the top edge of the tie-beam, which may next be drawn. Then draw the principal rafters parallel to and at their proper distance from the common ones.

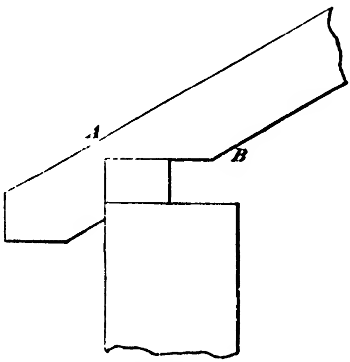

Fig 43

For the king-post, draw its centre line at right angles to the tie-beam through the apex of the common rafters, and set off on each side of it half the widths of the narrow and wide parts, as required. This would give the intersections through which to draw the abutments for the principal rafters and struts, when the width of both and the position of the struts are known. Then fill in the ridge and purlins to complete the elevation, placing the latter about midway between the pole-plate and ridge.

Strains.—The forces which operate, or which are brought into activity, in a truss, like that shown in Fig. 42, and all similar forms in roofing, are tension, compression and transverse strain. Each of the timbers composing the truss (Fig. 42) are subject to either tension or compression, and when the tie beam has to carry a floor or ceiling it is subjected to transverse strain also.

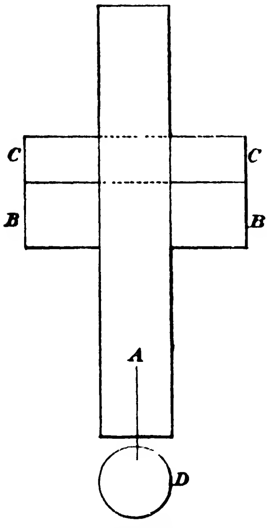

Fig 44

Tensional Strain.—When a piece of timber is subjected to a tensional strain it is being strained or pulled in the direction of its length. Thus, in Fig. 44, let the piece A be supported on two fixed pieces, BB, by having a bar or bolt, CC, passed through it as shown, and let a weight, D, be suspended from its lower end. Then the force of the weight D, acting on the piece A, is a tensional one, and the piece is said to be in tension, the tendency of the force being to *pull* the piece asunder.

Compression.—This strain is just the opposite

of the foregoing one. Instead of the piece being *pulled*, it is pressed in the direction of its length, the tendency of the force being to crush the piece endways.

Numerous examples illustrative of this strain will readily occur to the practical man. Fig. 45 is a simple illustration, and will clearly show the direction in which the force acts. Let A be a post, standing on a solid foundation, B, and let C be a weight laid on the upper end. Then the pressure or force will be downwards, and in the direction of the length of the post A. The post will therefore be in compression.

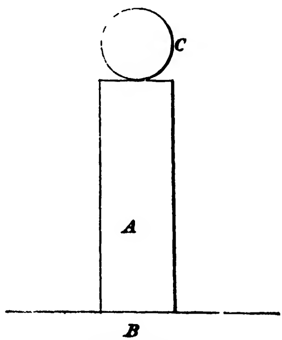

Fig 45.

Transverse Strain. — This strain is different to both of the foregoing ones. In those, the force acts lengthways of the piece. In this, on the contrary, the strain is crossways, and in an opposite direction to the length, the tendency being to *break* the piece asunder.

Thus in Fig. 46, let A be a beam supported at each end by the walls or posts, BB. Then by weighting it, as at C, transverse strain is

brought into play, the tendency of which is to break the beam asunder.

The weight or load may be anywhere in the length of the beam, or it may be distributed over its entire length; the action of the strain will be similar, its force depending upon the weight of the load the beam has to carry.

The parts in tension in the king-post truss

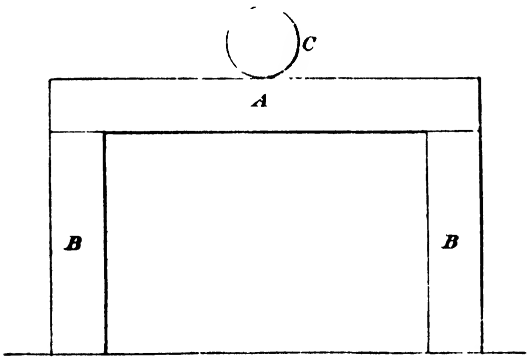

Fig 46.

(Fig. 42) are the tie-beam and king-post, and the parts in compression are the principal rafters and struts. This will be evident upon examination. The tie-beam has given to it what is termed a camber, *i.e.* it is raised in the middle from about $\frac{1}{2}$ in. to $\frac{3}{4}$ in. to every 10 ft. of its length above a straight line from end to end. To effect this, the shoulders at the bottom end of the king-post

are cut as much short of a straight line from end to end of the tie-beam as we wish to give it camber, every other shoulder at the same time being supposed to fit, and close home to their abutments.

Then when the iron strap is introduced, as will be explained presently, the pull or strain on the king-post is downwards, but the abutments and shoulders at each end of the principal rafters effectually prevent its movement in this direction. Consequently, the tie-beam is forced up to the shoulders at the lower end of the king-post, and is thus slightly stretched or strained on its upper edge. At the same time an increased pressure is thereby brought to bear on the abutments of the tie-beam in the direction of its length by the shoulders at the feet of the principal rafters, thus resolving it into a state of tension.

At the same time, the force acting on the principal rafters by the pressure of the abutments in the tie at their lower end, is upwards, or in the direction of their length, pressing the shoulders at their upper ends tightly against the abutments at the upper end of the king, thus resolving them into a state of compression.

While the upper end of the king-post is thus held in position by the shoulders of the principal

rafters, the force or strain made to act on it by introducing the iron strap or bolt at its lower end is downwards, and in the direction of its length, and it is thereby resolved into a state of tension. The king-post is by this means made to hold up the tie-beam in the middle, the weight of which is constantly suspended from it and straining it as stated.

All the foregoing forces are increased and maintained when the purlins, common rafters, and covering materials of the roof are added. The struts perform the office of posts, to enable the principal rafters to sustain the weight of purlins, common rafters, and other materials of the roof without sagging. They do not, strictly speaking, perform any office till the foregoing materials are added, and the roof completed. When this is done, pressure is brought to bear upon them endways, in the direction of their length, by the added weight of above materials, and they are thereby resolved into a state of compression.

*Shoulders and their Abutments.**—These are of great importance in framing trusses.

The strength of the frame depends not only upon the parts being properly fitted together,

* These are also called joggle joints.

but also to a great extent upon the direction in which some of them are drawn. The shoulders in the truss (Fig. 42) are the surfaces at the ends of the principal rafters and struts and the bottom end of the king-post, which take a bearing upon their several abutments.

Those on the bottom end of the king, being simply square, call for no remark except to say that there should be a short tenon about one-third the thickness of the piece, with a corresponding mortice in the tie-beam, a little deeper than the tenon is long.

The abutments are the surfaces corresponding to and receiving the bearing of their respective shoulders. Two are on the tie for the lower end of the principal rafters, two on the principal rafters for the upper ends of the struts, and four on the king-post for the upper ends of the principal rafters and the lower ends of the struts.

The whole of these should have mortice and tenon similar to those at the bottom of the king, the mortice being slightly deeper than their respective tenons are long.

The direction of the four abutments in the king-post, when they are made as shown in the figure, result naturally from the intersection of the edges of the principal rafters and struts, when drawn to their proper inclination and width with

the wide and narrow parts respectively of the king.

If the direction of these abutments when so drawn is such as to make the shoulders on the principal rafters and struts at right angles to their length, or very nearly so, no better form for these four joints can be desired or obtained. When simply cut square to the rafters and struts they present the least trouble of any in execution, and the greatest amount of resistance obtainable to receive the pressures brought to bear is thereby secured.

This direction for these joints can often be secured by properly adjusting the wide ends of the king-post. The size of the waist or narrow part of the king is the dimension obtained by calculations to be given subsequently. Let A, Fig. 47, be the width of the king at its narrowest part, and let AB be the direction and under edge of the principal rafter. From the intersection at A draw AC at right angles to AB, and a vertical line from C; the point where AC cuts the top edge of the rafter will give the extra width required for the top end of the king.

A similar process will give a similar direction for the joint for the struts at the lower end of the king. This would make the widths of the wide ends to differ top and bottom, which would not

be of the slightest consequence so far as the king-post itself is concerned.

This method of adjusting the wide ends of the king-post so as to obtain square shoulders for the rafters and struts cannot always be adopted. Other forms for these four joints must at times be

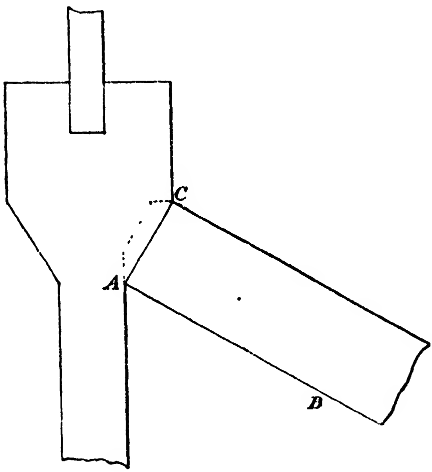

Fig 47.

resorted to, and it then becomes necessary to adopt the one that will best sustain the pressure to be resisted. When the shoulders become very oblique to the length of the struts or rafters they should be avoided if possible, and one that will better answer the purpose be adopted in its place.

Thus in Fig. 48 a joint made as at A would be preferable to that at B. The abutment corresponding to the shoulder at B would be useless for resisting the pressure of the strut, as the shoulders would slide on it nearly as easily as if the joint were a perpendicular one, the only portion offering any resistance to pressure being

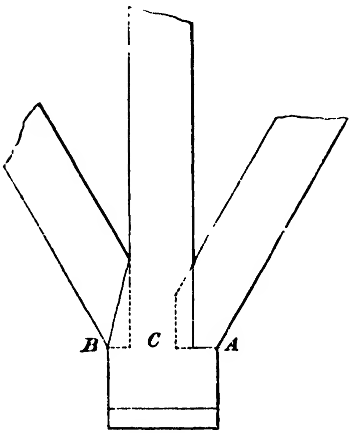

Fig 48.

the lower end of the tenon, as shown by the dotted lines at C. In the joint at A we get the same resistance to pressure by the lower end of the tenon, and in addition an abutting surface for the whole thickness of the strut to rest upon

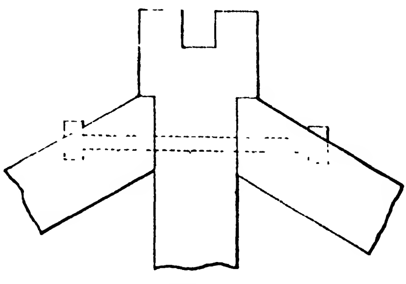

Fig 49.

The joints at the upper ends of the principal rafters, with a similar small projection in the width of the king-post, may be made similar to that at A. If a bolt is then put through both,

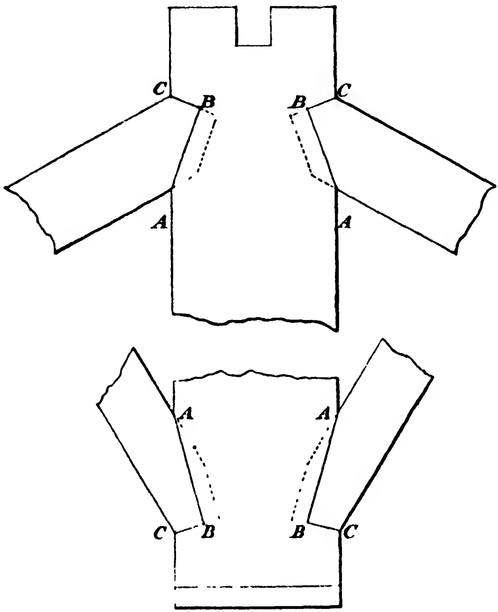

Fig 50.

as shown in Fig. 49, the joint will be a tolerably strong one.

In cases where the king has no projection at all beyond the waist in width, the joints both for

struts and rafters, may be made in the same way as those at the lower ends of the rafters, using a bolt the same as shown in the last Fig. The joints will then be as shown in Fig. 50.

The angle, B, Fig. 50, of these joints, and all similar ones, as a rule should be a right angle, for this reason, viz.:—The thrust or pressure on the rafter is, as already stated, in the direction of its length. But while this is so the tendency of any movement of the rafter downwards would be for its shoulder to slide on its abutment in the direction AB, and no better or more effectual resisting surface to such a movement can be obtained than one at right angles to AB, thus making ABC a right angle. The joints at the upper ends of the struts should be made similar to those in the last figure, and as shown at A, Fig. 51.

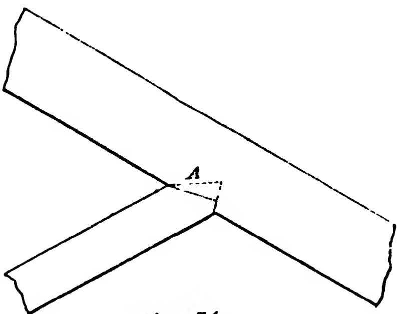

Fig 51.

In works of any importance, however, there is, or should be, sufficient projection in the width of the king-post top and bottom to obviate any necessity of resorting to such makeshifts as are

shown in Figs. 48, 49 and 50. When there is not width enough in the projection of the king to get the shoulders of the rafters and struts square

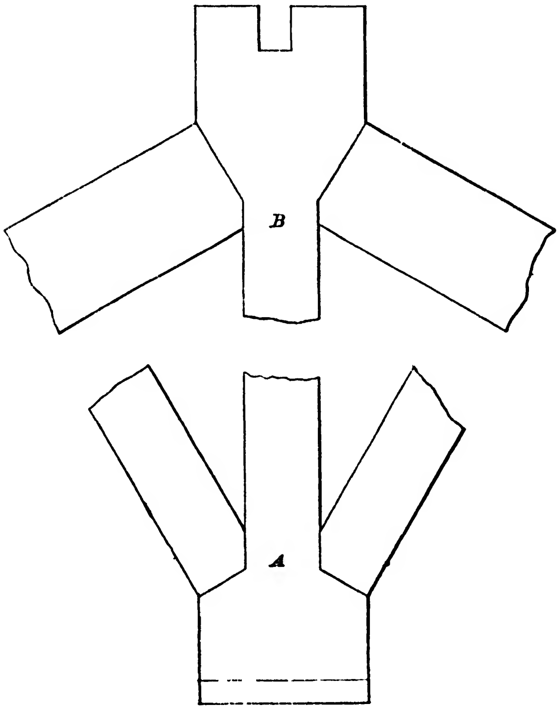

Fig 52.

across their whole width, they may be cut square part of the distance and the remainder made to fit the vertical edge of the king, as at A and B, Fig. 52.

One of the most important joints in the truss, Fig. 42, is that at the lower end of the principal rafters. The lower the pitch of the roof the more oblique the rafters become, and consequently the greater becomes their pressure lengthways of the tie-beam. But whether the roof be low or high pitched this joint is of importance and requires to be carefully and properly made. The plainer and less complicated the form chosen, so long as it is suitable to the purpose, the better. The line of the shoulders and their abutments should be visible from the outside when the parts are put together, so as to be able to see that they fit each other properly.

Double abutments should, as a rule, be avoided, for the reason that there is great difficulty in properly fitting such a joint with heavy timbers and getting each of the parallel abutments to take their proper share of the pressure, and also from the fact that the shrinkage of the timbers would have a much greater disturbing effect upon a double than upon a single abutment. They should be used only, as a rule, when the angle made by the rafter and tie-beam is very acute, as at A, Fig. 53, and when there is consequently a large bearing surface.

Various as are the forms advocated by the authorities on the subject for this particular joint,

it is doubtful if any of them are better or more efficient for the purpose, in all ordinary cases at least, than that shown in the elevation of the truss, Fig. 42, and to an enlarged scale in Fig. 54. It is of the simplest character possible, can be fitted together and executed with as little trouble as any, and if the work is properly

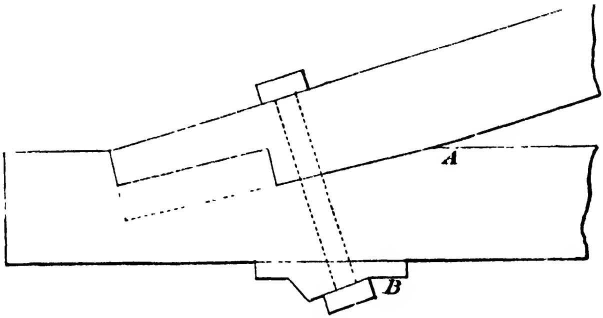

Fig 53.

and efficiently done, the thrust of the rafter must be great indeed before the joint will give way.

In making the joint as shown in Fig. 54, ABC should be a right angle for the reason as previously given in the description of Fig. 50. The tie-beam should be left as long as possible beyond the end of the rafter, so as to obviate, as far as can be done without using bolts, any possibility of the piece shearing off along the line BD.

It is said that the depth AB should be equal to

half the depth of the rafter, but it will be found less than this as a rule. Probably this is owing to a fear of weakening the tie-beam by letting the rafter in thus far, especially as this joint usually has no support immediately underneath it, except where the walls are unusually thick, or there are piers or corbels projecting sufficiently far to give it such support. We should say, as far as observation and experience can determine the

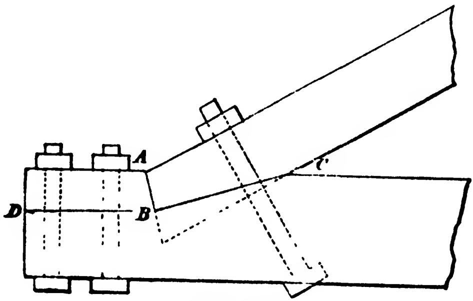

Fig 54.

matter, that one-third the depth of the rafter at the utmost is nearer the rule in general practice, and as far as our judgment enables us to form an opinion, we should consider this amply sufficient.

The whole of these joints should have a shallow mortice and short tenon from a quarter to one-third the thickness of the framing, so as to prevent any lateral movement of the parts.

The joint at C, Fig. 54, should be left very slightly free to allow for the settlement of the framing. This remark, however, should not be taken as applying to any of the other joints, as they are very much shorter than the foregoing one, except the stuff is very dry. This is not at all likely to be the case, and the shrinkage of the timber will then compensate for the settlement of the framing, and thus, as a rule, if the four joints in the king-post are made to fit, they will continue to do so as the wide ends shrink, and the truss settles down to its bearings, although the latter may perhaps take place somewhat sooner than the former.

The joint at the lower end of the rafter is usually secured by a bolt or strap, very often the former, partly perhaps because of the little trouble it gives, and its less expense than a strap, and also because as a rule very satisfactory results are secured by its use. When a bolt is used, a good, probably the best, direction for it is at right angles to the slope of the rafter, the head being let into the tie-beam, so as to get a bearing surface for it at right angles to the direction of the bolt; square iron plates or washers should be used under both head and nut, so as to obtain a larger bearing surface for the pressure consequent upon tightening up the bolt, and to prevent the

head and nut cutting into and bruising the timber injuriously.

Sometimes a check-plate of cast iron is used at the head of the bolt instead of letting it into the tie-beam, as shown at B, Fig. 53. The bevelled surface of the plate must be made so as to be at right angles to the bolt.

The primary object of the bolt is to hold the joint securely together, which it should do very effectually. It is not supposed to take any of the thrust of the rafter directly, but it is very evident that it does so indirectly to a considerable degree. Even supposing that the abutting piece at the end of the tie-beam was split off along BD, Fig. 54, the pressure downwards, and any movement of importance of the rafter in this direction would be successfully resisted as long as the bolt remained intact. And to force the head or nut off the bolt, which would require to be done before any such movement of consequence could take place, the thrust of the rafter would have to be very considerable indeed, supposing a good bolt with proper plates or washers is used. Of course, the abutting piece at the end of the tie-beam should not be split off. It should rather be made additionally secure by using one or two bolts as shown (Fig. 54), especially if the tie cannot be left sufficiently long for the purpose without them.

What are termed heel straps are sometimes used in preference to bolts for securing the foot of the rafter to the tie beam. One kind is shown at AB, Fig. 55. It is made wide enough inside to take the whole thickness of the tie-beam, and at its upper end, A, slots are made for the reception of an iron bearing-plate, which is laid across the back of the rafter, and a pair of iron wedges with which the strap can be tightened up. At B

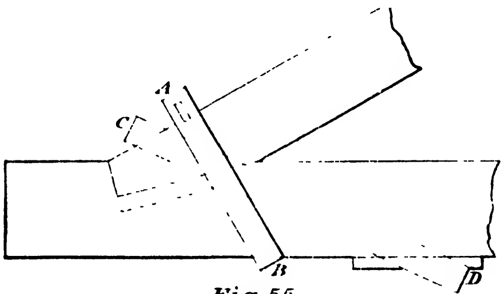

Fig 55

a check-plate, similar to that at B, Fig. 53, should be used so as to obtain a square bearing for the strap, instead of letting it into the tie-beam. The check-plate in this and similar cases will require to be as wide as the tie-beam is thick. It will also require fixing by coach bolts to prevent the possibility of any movement taking place when the strap is tightened up.

There is another kind of strap very similar to

the foregoing, but with screw ends (with nuts) welded on at the upper ends, a bearing-plate is laid across the back of the rafter, with holes drilled in it for the screw ends of the strap to pass through, which can then be tightened up by means of the nuts. Fig. 56 is a sketch showing this kind of strap.

The direction of the strap AB, Fig. 55, is the same as that of the bolt in Figs. 53 and 54, and, like them, its primary object is to secure the joint and hold it firmly together, and not to take the thrust of the rafter in any direct manner. So long, however, as the strap retains its position and remains intact, it will scarcely be possible for the rafter to move downwards to any appreciable extent, except on the supposition that the thrust will be so great as to either strip the nuts off the screw ends, or to force the bearing-plate of the strap into the timber at one or both ends of it.

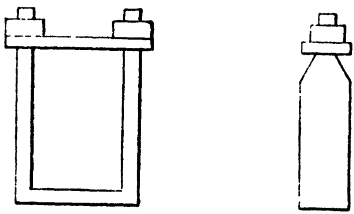

Fig 56.

If it is desired that the strap shall take the thrust of the rafter in a more direct way, it should be placed more in the position of CD, Fig. 55. If placed like this, check-plates, with a bearing

surface at right angles to the strap, will be necessary at both ends, and both will require fixing, or they will certainly be moved when the strap is tightened up. By some means also the lower end D of the strap should be secured in its place, or it will be liable to become loose and fall down as soon as the frame settles and the timbers shrink.

This position for the strap is recommended as being a much better one than that of AB, as it will resist in a much more direct manner the thrust of the rafter. It will be evident, however, that the capability of the strap for effectually resisting this thrust will be greatly, if not altogether, dependent upon whatever the check-plates are fixed with. These, therefore, should be fixed in their respective places as securely as possible, so that the one under the tie-beam may not be pulled outwards, or the one on the back of the rafter upwards, when the strap is tightened up, and so that they shall present such resistance when they receive their bearings as will prevent any part of the joint giving way.

A better kind of strap and a better position for it also is that shown in Fig. 57, No. 1, which is a geometrical elevation of what is considered a good form of joint for the lower end of the rafter. Nos. 2 and 3 are a perspective representation of the same joint, showing the parts detached. This is

called a bridle joint. The bridle (A, No. 2) is a piece from one-fourth to one-fifth the thickness of the tie-beam left in the middle, a corresponding piece (A, No. 3) being cut out of the middle of the rafter, the sides or cheeks of which run down and fit into recesses cut on each side of the bridle in the tie, as shown.

The bridle strengthens the abutments of the tie-beam, which should be cut square to the slope of the rafter. That at D, on the rafter, should be cut square to the direction of the strap, which is placed as shown in order that it may resist more directly than is possible with any of the preceding ones the thrust of the rafter. The lower end, E, is secured in its place by a bolt through strap and tie-beam. The upper end, D, may be as shown, or it may be made with screw ends and nuts, and a bearing-plate the same as Fig. 56, which would be preferable as it could then be lengthened or shortened as required.

To avoid the double abutment, which, as previously stated, is objectionable if the rafter is not too deep, the joint may be made as in Fig. 58, making ABC a right angle, and the bridle being continued through in a line with the top of the beam, as shown by the dotted line, AC.

If too much of the tie-beam would be cut away by making the joint as in the last example, it may

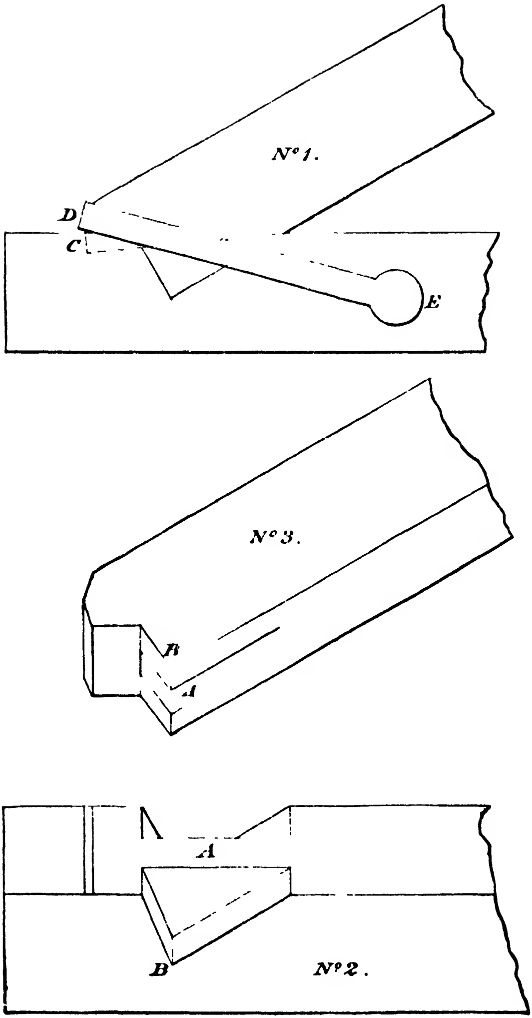

Fig 57.

be made as in Fig. 59, making the depth, AB, equal to about one-third the depth of the rafter, and ABC a right angle; also retaining the bridle as in the previous example.

The last method, Fig. 59, would form a good strong joint, and would be much less trouble to make than that shown in Fig. 57, with a far greatly probability of the parts being properly fitted. The strap should be made with screw ends and nuts, as the bearing-plate can then be so much more easily adjusted to the abutment of the rafter than if it is made without them.

No doubt, the straps we have just been describing resist more directly than bolts the downward thrust of the rafter. Those shown at CD, Fig. 55, and Figs. 57, 58, and 59, require screwing up only just enough to bring the bearing-plate up to the abutment and adjusting it properly to its place at the foot of the rafter, or the bearings on that and the tie abutment will become unequal. If screwed up too tightly the rafter would be forced upwards on the shoulder, BC, and away from the abutment, AB.

The foot of the rafter, when up to its bearings, should press equally on the bearing-plate of the strap and the abutment in the tie. They have no holding-down power whatever, and it would be found an easy matter to lift the rafter entirely

clear of its mortice and abutments by a very slight leverage after the truss has been put together.

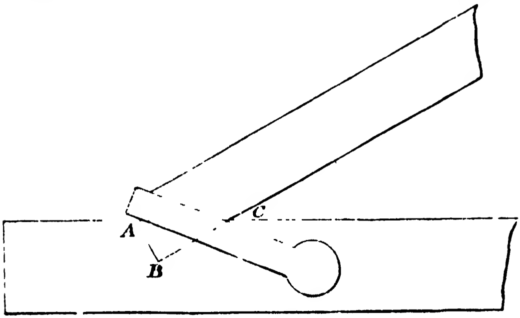

Fig 58.

This defect, if we may consider it to be such, is remedied, as far as it is possible to do so, when

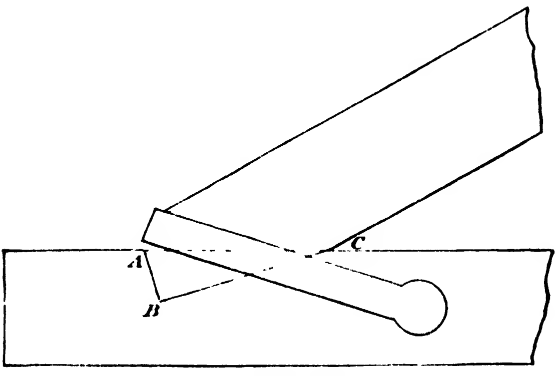

Fig 59.

the truss is set up into position and weighted with the other parts of the roof.

Bolts, on the contrary, bind the joint securely together, and hence their want of a more direct resistance to the thrust of the rafter is greatly compensated for. They will be found to answer every requirement in a great majority of cases. They give very little trouble, and if made sufficiently strong, with heads and nuts in proper

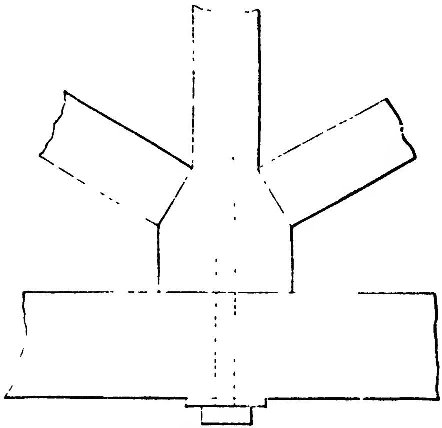

Fig 60

proportion and good plates or washers (or check-plates, as at B, Fig. 53), such a joint as is shown in Fig. 54, which is the simplest form possible, would give very satisfactory results in all ordinary cases.

Bolts are also sometimes used for supporting the centre of the tie-beam and holding it up

closely to the shoulders at the lower end of the king-post. The bolt passes through the beam and, as far as may be necessary, into the king, a nut being let into the latter from one side into which the bolt is turned by applying a spanner to its head until the top edge of the beam is forced tightly up to the shoulders of the king-post.

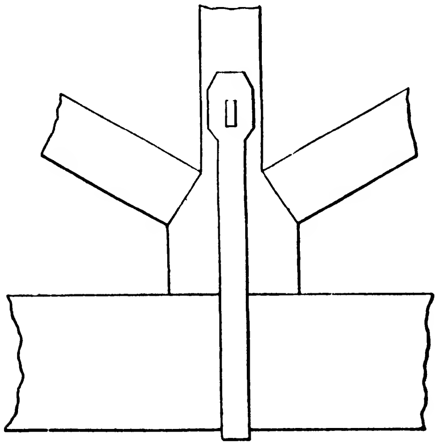

Fig 61

Fig. 60 is an elevation of the lower end of the king and part of the tie-beam, showing the bolt in position as sometimes used. The strain on the bolt being in the direction of its length entirely, the head and screwed end with nut should be made sufficiently strong to support the weight it may have to carry.

A better plan, however, is to use a stirrup strap with gibs and wedges in place of the foregoing bolt, as shown in elevation at Fig. 61, and in section at Fig. 62. The upper end of the strap has a slot in it for the reception of the gibs and wedges, a corresponding slot being morticed through the king-post. The gibs are made to clip over the sides of the strap and prevent them from spreading outwards when the wedges are driven in. They also form a solid bearing to take the pressure of the wedges. The slot in the king-post should be about ½ in. higher than that in the strap when the beam is up to the shoulders, or very nearly so. Then as the wedges are driven they will press the lower gib on to its bearing in the lower end of the slot in the king-post, and the upper one on to its bearing in the upper end of the slot in the strap, and both strap and beam will be lifted and the latter forced tightly up to the shoulders of the king-post.

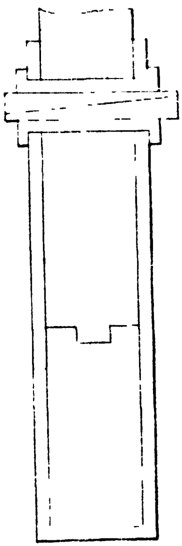

Fig 62.

This is shown in Fig. 63, which is purposely exaggerated.

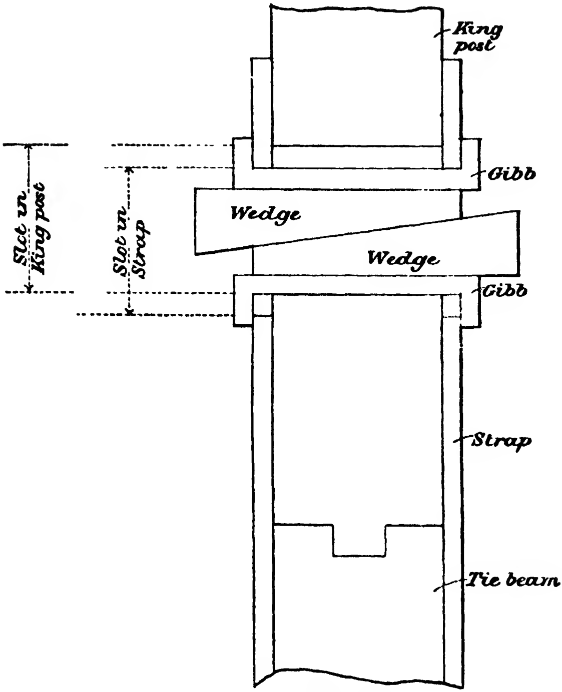

Fig 63.

The Queen-post Truss and Roof.—Fig. 64 is an elevation of a queen-post truss. The names of the different parts are as follows :—

A,	Tie-beam.	G,	Purlins.
B,	Principal rafter.	H,	Ridge.
C,	Queen-posts.	K,	Common rafter.
D,	Struts.	L,	Pole-plates.
E,	Straining-beam.	M,	Cletes.
F,	Straining-sill.		

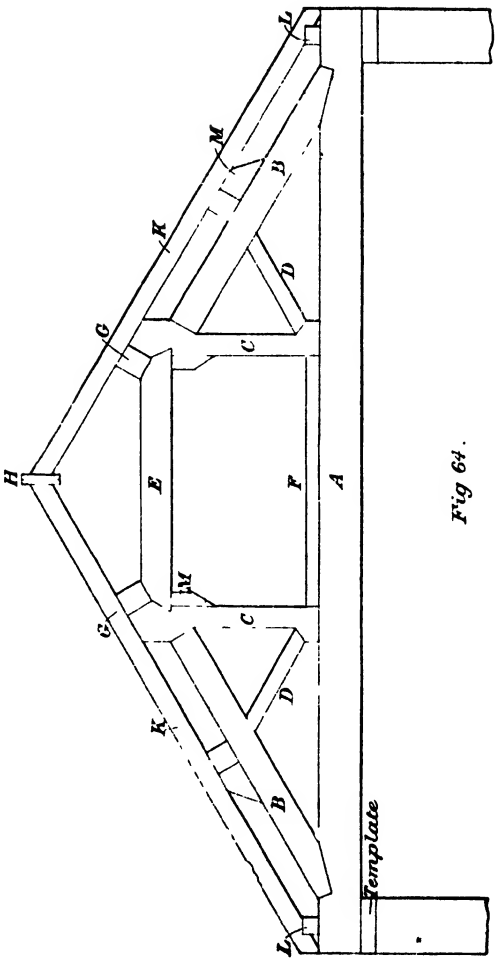

Fig 64.

The parts in tension are the tie-beam and the two queens. Those in compression are the principal rafters, the struts and the straining beam and sill. There will be a cross strain also on the tie-beam if it has to carry a floor or ceiling; also on the straining-beam if it has to support a floor, as it sometimes does.

The queens, as a rule, are placed so as to divide the opening between the walls into three equal parts. The joints at the ends of the principal rafters and struts may be made the same as the corresponding joints in the king-post truss, Fig. 42. The straps or bolts at the lower ends of the principal rafters and queens may be similar to those for corresponding positions in Fig. 42.

The widths for the wide ends of the queens may be adjusted in the same way as the wide ends of a king-post, so as to obtain square shoulders for the rafters and struts. The straining-sill, F, is for keeping the lower ends of the queens at their proper distance apart, the pressure of the struts having a tendency to force them nearer together. The straining beam, E, acts in the same way at the upper ends of the queens, the pressure of the rafters tending to force them over and nearer together.

The joints at the ends of the straining-beams should have a shallow mortice and short tenon,

and be made as shown at A, Fig. 65, with a clete underneath as at B, well secured to the queen by good spikes or coach screws. These joints should also have iron straps, one on each opposite side, secured with bolts. The form shown in the figure

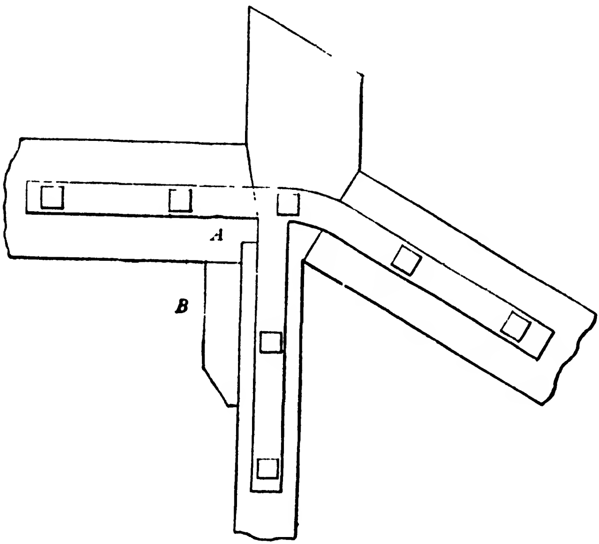

Fig 65.

may be varied to suit particular cases, but it will be found sufficient for all ordinary purposes.

The purlins are usually placed so as to divide the bearings of the common rafters into three equal parts, or as near this as can be done conveniently. The lower one should also be placed

as nearly as possible over the upper end of the strut or, rather, the latter should be framed into the rafter immediately under the purlin, if it be possible to do so without making it lie in too horizontal a position. The best angle for the strut to make with the rafter, and the one by which the greatest amount of support is obtainable, is a right angle. This, however, it is scarcely ever possible to secure when the lower end of the strut is made

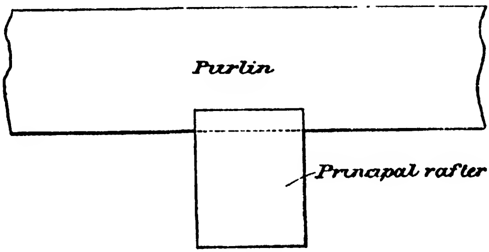

Fig 66.

to rest, as it invariably does, upon an abutment in the queen or king post.

Caulking or Cogging.—The purlins are usually caulked or cogged at their bearing places on the principal rafters, which is a better form of joint than a simple notch. In the latter the whole thickness of the principal rafter is let into the purlins, as in Fig. 66, to the depth of about an inch, thus really reducing the depth and strength of the purlin by so much. It is better not notched

at all than to do it like this. A better plan would be to simply let the purlin rest upon the back of the principal rafter and trust to good and efficient spiking to that and the cletes (M, Fig. 64), to keep the trusses in position, thus securing the whole depth and strength of the purlins.

In the caulked joint the purlin is let down into the rafter the same distance as in the simple notch joint, but instead of cutting it out for the whole

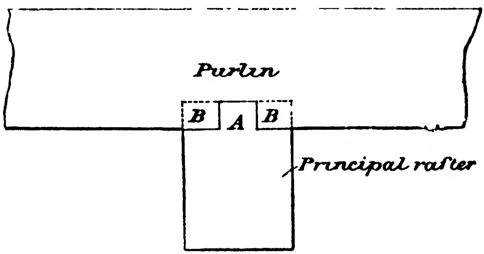

Fig 67

thickness of the rafter it is cut out only for about one-third, as at A, Fig. 67, the whole depth taking a bearing in notches cut in the remaining one-third on each side on the back of the rafter, as at BB, the piece or cog, A, being left to fit into the notch in the purlin.

The pole-plate may be treated in the same way when the tie projects sufficiently far beyond it, but when it has to be cut off rather close it is better to make the joint as in Fig. 68.

Joints for Lengthening the Purlin, &c.—A very usual form of joint for lengthening the purlin is shown in Fig. 69, and is called a scarfed joint. It is not a good one for the purpose, as it is some trouble to

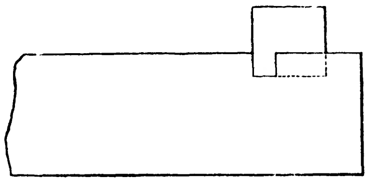

Fig 68

make, and weakens the timbers also for taking a cross strain. Strictly speaking, this form of scarf is for timbers subject to a tensional strain,

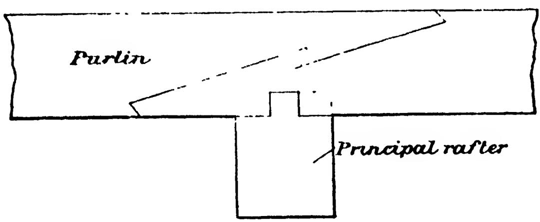

Fig 69.

whereas that upon the purlins is transverse, they having to support those parts of the roof immediately above them. The better way to make these joints is to simply let the timbers abut square against each other over the centre of the principal rafters, and secure them together by fish-plates of wood or iron. It then becomes what is termed a fished joint, of which Fig. 70 is an illustration.

The fish-plates are placed on opposite sides of the timbers and secured in their places by bolts, as

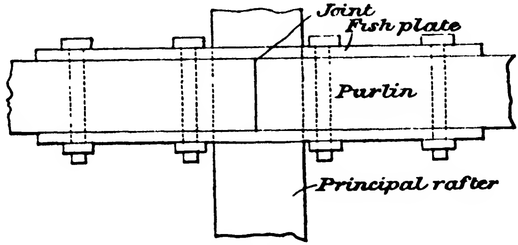

Fig 70.

shown. The advantages of this form of joint are, little trouble in making, and the retention of the whole depth of the purlin for taking the transverse strain to which it is subject.

The joints for lengthening the wall or pole plates should be made as shown in Fig. 71, as this form gives the timbers a good hold on each other

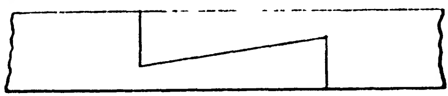

Fig 71.

lengthways when they are loaded with the other parts of the roof.

The following proportions for bolt nuts, washers, and straps are those given by various authorities. They will be found suitable for the foregoing roof trusses, and others of a similar character, and

should be adhered to as nearly as possible. Supposing the diameter of the bolt to be 1 in., then the head and nut, whether square or hexagon, should be $1\frac{3}{4}$ in. from side to side.

Thickness of head		$\frac{3}{4}$ the diameter of bolt.	
,,	nut	1 to $1\frac{1}{8}$	,,
,,	washer	$\frac{3}{8}$ to $\frac{1}{2}$	,,
Diameter of	,,	$3\frac{1}{2}$	,,

Washers as sometimes used are utterly useless for the purpose, being much too thin and small. The above dimensions should not be reduced, except to a very trifling extent, if they are to be at all effective.

Straps.—The dimensions given for these are as follows:—When the longest unsupported part of the tie-beam—

is 10 ft.	the strap should be		1 in. by $\frac{3}{16}$ in.
,, 15 ft.	,,	,,	$1\frac{1}{2}$ in. by $\frac{1}{4}$ in.
,, 20 ft.	,,	,,	2 ins. by $\frac{1}{4}$ in.

These dimensions may also be used for the straps at the feet of the principal rafters. They are those given by competent authorities. We should not consider them to err at all in being too large—rather the reverse, and should think they might be increased somewhat with advantage. King-post trusses are considered suitable for spans up to 30 ft.

From 30 ft. up to about 50 ft. trusses with

two queens are the most suitable; and for spans from 50 ft. and upwards trusses with four queens should be used.

When the span becomes very wide, timbers of sufficient length cannot often be obtained for the tie to be in one piece. It is then necessary to joint two pieces together lengthways to obtain the required length.

This should be done by a fished joint, or fished scarf—preferably the former—of which there are several forms.

The simplest and, according to competent authorities, the best and strongest is to simply let the ends of the timbers abut square against each other, and connect them together by means of fish-plates, either of wood or iron, placed on opposite sides in a similar way to that shown for the joint in a purlin, as Fig. 70.

In the tie-beam, however, the strain we have most often to contend with is a purely tensional one, and in which the two pieces have to be connected so securely as to prevent any possibility of the joint being forced asunder by the strain acting in that direction.

Fig. 72 shows a good form of fished joint, in which iron fish-plates are used, the ends running past each other on the opposite sides, as shown, and, being indented into the tie, relieve the bolts

of much of the pressure that would otherwise be

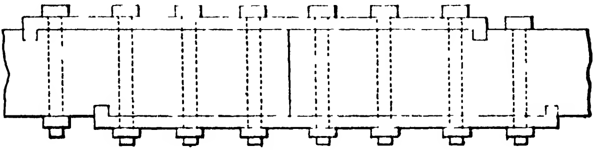

Fig 72.

thrown upon them. The bolts should be made square and passed through the timber so as to

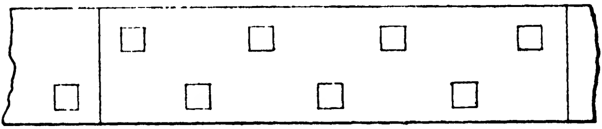

Fig 73.

present a square face at right angles to the stress, and be placed as shown on plan at Fig. 73.

They must not be placed too near either of the ends of the fish-plates, or the butting ends of the joint.

Wooden fish-plates are tabled or indented into

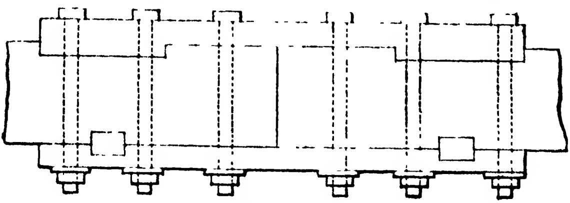

Fig 74.

the tie, as shown in the upper part of Fig. 74, or

hardwood joggles or keys are used, as in the lower part.

When they are tabled in, as in the upper part of the figure, the effective area of the tie is very much weakened.

But whichever method is employed with wooden fish-plates, they always present a clumsy appearance, and are very liable to shrink and cause loose joints.

The iron plates undoubtedly possess a great advantage over wooden ones in this and other respects, and should always be preferred for works of a permanent character, limiting the use of wooden ones to temporary structures only, except when they are hidden from view, and their clumsy appearance is consequently of no importance.

Scarfing.—In scarfed joints the ends of the timbers to be connected overlap each other, as in Fig. 69. This is a very common form of scarf for lengthening purlins, for which purpose it may perhaps answer very well, although, as shown at Fig. 70, a plain fished joint is much stronger and less trouble to make. It (Fig. 69) is altogether unsuited, however, for lengthening a tie-beam. Even with fish-plates it would not be a good one, on account of its being rather too complicated, and the direction of the surfaces in contact not

being at right angles to the pressure of the bolts.

If a fished scarf must be used or should be preferred for lengthening the tie, the best and simplest form for the purpose would be as shown in Fig. 75, from which it will be seen that the

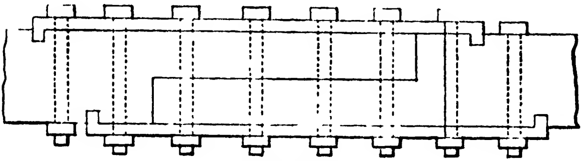

Fig 75.

surfaces in contact are at right angles to the pressure of the bolts, and that there is no tendency of the pieces to slide one on the other as there would be in a bevelled joint. The bolts should be placed on plan, as shown in Fig. 73. If bolts only and no fish-plates are used, we should still consider the scarf, Fig. 75, the best, for reasons already given.

There are several other ingenious forms of scarfed joints in which both bolts and fish-plates are dispensed with. As, however, they are altogether useless for the purpose under consideration, we shall not reproduce them here.

Tredgold gives the following rules for the proportion which the length or overlap of a scarf should bear to the depth of the tie.

	Without bolts.	With bolts.	With bolts and indents
Oak, ash, &c.	6	3	2
Fir timber	12	6	4

In theory the foregoing rules may be correct enough, but in practice some of the joints if made according to them would look strangely long, notably that without bolts for fir timber, in which if the tie were 12 ins. deep the length of the scarf would be 12 ft., which, to say the least, would appear rather long. Such forms of joints, however, are not good ones and cannot be recommended. The best and most economical, both as regards labour and material, is a plain fished joint.

CHAPTER IV.

RULES FOR FINDING THE SCANTLINGS OF ROOF TIMBERS.

IN dealing with this part of our subject we purpose giving the rules and formulæ that are used for finding the sizes of the various timbers constituting the roofs in the usual way, *i.e.* by using letters to represent numbers. This gives them an algebraical form. Really, however, there is no algebra about them. By using letters as indicated the rules can be stated much more shortly and simply, and when once understood no further difficulty in reference thereto need be experienced.

Sometimes the rules are given entirely in words, and some of them produce very extraordinary results. This, of course, is not because words are used to express the rules, but because the rules themselves are at fault. It therefore becomes necessary not only to express the rules in an intelligible manner, but also to choose those that

will give intelligible and reasonable results so far as the sizes of the timbers can be determined thereby.

The greater part of the rules about to be given are from Hurst's "Architectural Surveyor's Handbook," and some from Tredgold's and Tarn's "Carpentry." In using them it must be remembered that they apply primarily to roofs having a one-fourth pitch, which is equal to an inclination of $26\frac{1}{2}°$ or $27°$ to the horizon.

The following brief particulars and explanations in reference to the rules and formulæ as they are generally given may be of service to some. They will also show the necessity and advantage of clearly understanding how to proceed in attempting to apply them in practice. Indeed, it may safely be said that the greatest difficulty in connection with them is to thoroughly understand their meaning and requirements, and that to anyone possessing this understanding and an ordinary knowledge of arithmetic the practical application of the rules may become a very simple matter.

Letters whose values are to be multiplied by one another are placed side by side only, the sign ($\times$) of multiplication being omitted. Thus, ab means, that the number represented by a is to be multiplied by the number represented by b, so that if $a = 3$ and $b = 4$, their product would be

12. So also when a number and letter are placed side by side without the sign of multiplication between them, as $6a$, this simply means that 6 is to be multiplied by the number represented by a, and if $a = 6$ the formula may be stated thus: $(6 \times a) = (6 \times 6) = 36$. Here is a similar one: $50b$. This means that 50 is to be multiplied by the number represented by b, and if $b = 8$ the formula may be stated thus: $(50 \times b) = (50 \times 8) = 400$.

Division is expressed in the same way as in fractions, *i.e.* with a horizontal line between the dividend and divisor. Thus, if a is to be divided by b it is written simply $\frac{a}{b}$. Let $a = 12$, and $b = 4$. It may then be stated and worked out as follows: $\frac{a}{b} = (a \div b) = (12 \div 4) = 3$. If the product of two or more letters is to be divided by the product of two or more others it is written similarly. Thus $\frac{ab}{cd}$ means that the product of a multiplied by b is to be divided by the product of c multiplied by d. Let $a = 6$, $b = 8$, $c = 3$, and $d = 2$. The rule may then be stated and solved as follows:

$\left(\frac{ab}{cd}\right) = \left(\frac{6 \times 8}{3 \times 2}\right) = \left(\frac{48}{6}\right) = 8$. So also when a

number is used in a similar position, as $\frac{ab}{15\,c}$. This means that the product of *ab* is to be divided by the product of 15 times *c*. Suppose $a = 20$, $b = 9$, and $c = 2$. We may then say—

$$\left(\frac{ab}{15\,c}\right) = \left(\frac{20 \times 9}{15 \times 2}\right) = \left(\frac{180}{30}\right) = 6.$$

Here is another similar one: $ab = \frac{cd}{50\,e}$. The meaning of this formula is that the product of *ab* must be equal to the product of *cd* divided by the product of 50 times *e*, and what is required is to find the value of the product of *a* multiplied by *b*. Let $c = 900$, $d = 10$, and $e = 9$. Then $ab = \left(\frac{cd}{50\,e}\right) = ab = \left(\frac{900 \times 10}{50 \times 9}\right) = ab = \left(\frac{9{,}000}{450}\right) =$ $ab = 20$, which is the value of *a* multiplied by *b*.

By making a slight difference in the last formula, we may use it for finding the dimension of a queen-post. Instead of stating it as we have done, let it be as follows: $ab = \frac{c^2d}{50\,e}$. By attaching a certain value to the letters the result will be the same as in the previous case, the difference being in the method of stating the rule.

Instead of *c* being equal to 900, we make it equal to 30, and square it as denoted by the small index figure (^{2}) on the right hand. The product

of ab will represent the area of the small part of the queen-post in square inches, and is found as shown in the last example.

Thus: $ab = \dfrac{c^2d}{50\ e} = ab = \left(\dfrac{30^2 \times 10}{50 \times 9}\right) = ab = \left(\dfrac{900 \times 10}{50 \times 9}\right) = ab = \left(\dfrac{9{,}000}{450}\right) = ab = 20$, the area of the queen-post in square inches at its smallest part.

When the number represented by a letter is required to be cubed it is written a^3, i.e. $a \times a \times a = a^3$, or if a denote 4 it will be $4 \times 4 \times 4 = 64$.

When the square root of a number is required it is indicated in the usual way. Thus the formula: $a = \sqrt{b}$ means that a is equal to the square root of b, and what is required is to find the value of a. To do this we simply find the square root ($\sqrt{\ }$) of b. Suppose $b = 9$, the square root of which is 3; then the value of a will be 3. The rule may be solved thus: $(a = \sqrt{b}) = (a = \sqrt{9}) = (a = 3)$.

The same sign with the addition of a small figure is used to indicate other roots. Thus $\sqrt[3]{27}$ indicates that the cube root of 27 is required, which is 3, and $\sqrt[4]{16}$ indicates the fourth root of 16, which is the square root of the square root, and is 2. If the square, cube, or fourth root of two or

more numbers is required, it is expressed thus: $a = \sqrt{bc}$, which means that a is equal to the square root of the product of b multiplied by c.

Suppose $b = 8$ and $c = 2$, their product will be 16, the square root of which is 4, which will also be the value of a. The formula may then be written and worked out thus: $(a = \sqrt{bc}) = (a = \sqrt{8 \times 2}) = (a = \sqrt{16}) = (a = 4)$.

Another method of indicating the root required is by placing a fractional index above the number on the right hand. Thus the formula: $a = \sqrt{\overline{bc^{1/2}}}$ means that a is equal to the square root of the product of b multiplied by the square root of c.* Suppose $b = 4$ and $c = 9$, the square root of which is 3, then $(a = \sqrt{\overline{bc^{1/2}}}) = (a = \sqrt{\overline{4 \times 9^{1/2}}}) = (a = \sqrt{\overline{4 \times 3}}) = (a = \sqrt{12}) = (a = 3{\cdot}465)$ nearly.

This last formula is the one used for finding the dimensions of a straining-beam. Stated in full it will be as follows, d representing its depth: $d = \sqrt{\overline{ab^{\frac{1}{2}}}} \times 0{\cdot}9$. This means that the depth of the straining-beam will be equal to the square root of the product of a multiplied by the square root of b, and this product multiplied by $0{\cdot}9$, a being

* This is indicated by the horizontal line above bc (called a vinculum), and denotes that they are to be treated as one number.

the length of the beam, and b the span of the roof, both in feet.

Let $a = 12$, the length of the beam, and $b = 40$, the span of the roof. We then proceed to solve the formula as follows. $(d = \sqrt{ab\,\tfrac{1}{2}} \times 9{\cdot}9) = (d = \sqrt{12 \times 40}\tfrac{1}{2} \times 0{\cdot}9) = (d = \sqrt{12 \times 6{\cdot}325} \times 0{\cdot}9) = (d = 8{\cdot}8 \times 0{\cdot}9) = (d = 8$ ins.), nearly the depth of the beam.

All the foregoing forms of expressions occur in the formulas that are used for finding the dimensions of the various timbers in king and queen post roofs, and as the greatest difficulty in applying them is surmounted by having a clear apprehension of their meaning and requirements, we have deemed it advisable to enter thus fully into explanations concerning them.

TABLE OF SQUARE AND CUBE ROOTS TO THREE PLACES OF DECIMALS.

Square roots.		Cube roots.	
1	= 1	1	= 1·000
1½	= 1·225	1½	= 1·145
2	= 1·415	1¾	= 1·206
2½	= 1·582	2	= 1·260
3	= 1·733	2½	= 1·357
3½	= 1·871	3	= 1·450
4	= 2·000	3½	= 1·519
4½	= 2·122	4	= 1·588
5	= 2·237	4½	= 1·651
5½	= 2·346	5	= 1·710
6	= 2·450	5½	= 1·766
6½	= 2·550	6	= 1·818
7	= 2·646	6½	= 1·867
7½	= 2·739	7	= 1·914
8	= 2·829	7½	= 1 958
8½	= 2·916	8	= 2·000

(*Continued on next page.*)

Square roots.	Cube roots.
$9 = 3{\cdot}000$	$8\frac{1}{2} = 2{\cdot}050$
$9\frac{1}{2} = 3{\cdot}083$	$9 = 2{\cdot}081$
$10 = 3{\cdot}163$	$9\frac{1}{2} = 2{\cdot}118$
	$10 = 2{\cdot}155$

RULES.

Let a = area of section, b = breadth, d = depth — in inches.
L = length of piece, S = span of roof — in feet.

To find the Dimensions of the Tie-beam when it has to Support a Ceiling only.

$$d = \frac{L}{\sqrt[3]{b}} \times 1{\cdot}47 \text{ for pine,* or } 1.52 \text{ for oak.†}$$

This rule stated in words would read as follows:—The depth (d) equals the length (L) of the longest unsupported part, divided by the cube root of the breadth (b), and the quotient multiplied by 1·47. The product will be the depth required.

The longest unsupported part of a tie-beam in a king-post truss may be taken at half its total length. Suppose the length of the tie is 20 ft., L in the formula will represent 10 ft. Let the breadth or thickness be 4 ins., and b will represent that number, the cube root of which is 1·588 (see preceding Table of Roots). We

* Pine or northern pine means the baulk timber usually employed in roofing.

† The multipliers for oak will not be noticed further than giving them as in the rules

then proceed as follows to find the depth or value of d:—

$$\left(d = \frac{L}{\sqrt[3]{b}} \times 1{\cdot}47\right) = d = \left(\frac{10}{\sqrt[3]{4}} \times 1{\cdot}47\right) =$$
$$\left(d = \tfrac{10}{1{\cdot}588} \times 1{\cdot}47\right) = (d = 6{\cdot}29 \times 1{\cdot}47) =$$
$$(d = 9{\cdot}2463).$$

The inclosures within the brackets denote each distinct operation in the procedure. Thus:— the first is simply the rule. In the second we omit the $\frac{L}{\sqrt[3]{b}}$ and substitute $\frac{10}{\sqrt[3]{4}}$ in its place, 10 being the length of the unsupported part of the tie, and 4 its thickness. In the third we have $\frac{10}{1{\cdot}588}$ in place of $\frac{10}{\sqrt[3]{4}}$ as given in the second, the denominator 1·588 being the cube root of 4 (see Table of Roots). In the fourth, in place of $\frac{10}{1{\cdot}588}$, we have 6·29, which is obtained by dividing 10 by 1·588. This reduces the operation to one of simple multiplication, for by multiplying 6·29 by 1·47, we obtain 9·2463, as given in the fifth, and we thus find the value of d, or depth of the tie to be 9·3 ins. nearly. This would give a tie of 9 or $9\frac{1}{2}$ by 4, which would make a good and efficient one for a span of 20 ft.

In a queen-post truss with two queens one-third the length of the tie should be taken, and in any kind of truss the longest distance there may be

between any two adjacent points of support in the length of the tie should be taken for L in the formula.

To find the Dimensions of the King-post.

$a = L\,S \times 0{\cdot}12$ for pine, or $\times\ 0{\cdot}13$ for oak.

What is required here is to find the sectional area (a) of the waist or smallest part of the king-post, and all we have to do is to multiply the length (L) by the span (S) and this product by 0·12 to obtain the required scantling. Let $L = 7$ ft., the length of the king, and $S = 26$ ft., the span of the roof. Then $(a = L\,S \times 0{\cdot}12) = (a = \overline{7 \times 26} \times 0{\cdot}12) = (a = 182 \times 0{\cdot}12) = (a = 21{\cdot}84)$. This gives, say, 22 ins. as the sectional area of the king-post. If this is divided by the breadth the quotient will be the depth, or by the depth and the quotient will be the breadth. We should then have the dimensions as $5\frac{1}{2} \times 4$, or $5 \times 4\frac{1}{2}$, whichever will best suit the thickness of the other timbers.

To find the Dimensions of the Queen-posts.

$a = L\,p \times 0{\cdot}27$ for pine, or $\times\ 0{\cdot}32$ for oak, p being the length in feet of that part of the tie-beam supported by the queen-post, which when two queens are employed should be taken at one-third the total length of the tie or span. Let

$L = 7$ ft., the length of the queen-post, and $p =$ 13 feet (one-third the total length of a span of 39 feet). Then proceed thus:—$(a = \overline{L\,p} \times 0{\cdot}27) = (a = \overline{7 \times 13} \times 0{\cdot}27) = (a = 91 \times 0{\cdot}27) = (a = 24{\cdot}57)$. This gives 24 ins. as the sectional area of the queen, with which a 6 ins. × 4 ins. scantling exactly coincides.

To find the Dimensions of the Principal Rafters when there is a King-post.

$$b\,d = \frac{S^2 T}{50\,R} = \text{sectional area in square inches,}$$

T being the distance apart of the trusses, and R the rise of the roof, both in feet. That is to say, the breadth and depth (bd) multiplied together should be equal to the span squared (S^2), multiplied by the distance apart of the trusses (T), and this product divided by 50 times the rise (R) of the roof. What is required then in working out the formula is simply to find the quotient of ($S^2\ T$) divided by ($50\ R$).

Let the span of the roof be 20 ft., the distance apart of the trusses 10 ft., and the rise 5 ft. We may then proceed as follows:—$\left(bd = \frac{S^2 T}{50\,R}\right) = \left(bd = \frac{20^2 \times 10}{50 \times 5}\right) = \left(bd = \frac{400 \times 10}{250}\right) = \left(bd = \frac{4{,}000}{250}\right) = (bd = 16)$. The sectional area of the

rafter is thus found to be 16 ins., and a scantling of 4 × 4 would exactly meet it.

To find the Dimensions when there are two Queen-posts.

$$bd = \frac{S^2 T}{40\ R}.$$

Let the span of the roof be 40 ft., the distance apart of the trusses 10 ft., and the rise 10 ft. As in the last example what we have to determine is the product of $b \times d$ or sectional area of the rafter, which should be equal to the quotient of (S^2T) divided $(40\ R)$. The procedure is exactly the same as in the previous case. Thus:

$$\left(bd = \frac{S^2 T}{40\ R}\right) = \left(bd = \frac{40^2 \times 10}{40 \times 10}\right) = \left(bd = \frac{1{,}600 \times 10}{400}\right) = \left(bd = \frac{16{,}000}{400}\right) = (bd = 40).$$

We thus find that $b \times d$ (the breadth and depth of the rafter) should be equal to 40 square ins. To meet this requirement we may make the rafters 6 × 6½, 8 × 5, or 7 × 6, whichever will coincide best with the thickness of the other timbers.

When there are four queens the formula for determining the scantling of the rafters is:

$$bd = \frac{S^2 T}{38\ R},$$

which is solved in just the same way as the preceding example.

To find the Dimensions of the Straining-beam, the depth of which should be to its thickness as 10 to 7, or as near to this proportion as possible.

$$d = \sqrt{L\ S^{\frac{1}{2}}} \times 0{\cdot}9.$$

That is to say, the depth should be equal to the square root of the product of L multiplied by the square root of the span ($S^{\frac{1}{2}}$), and this root multiplied by 0·9. The quotient will be the depth. Let the length of the beam be 12 feet and the span 40 feet, the square root of which is 6·325. The depth (d) is then found as follows: $(d = \sqrt{L\ S^{\frac{1}{2}}} \times 0{\cdot}9) = (d = \sqrt{12 \times 40^{\frac{1}{2}}} \times 0{\cdot}9)$ $= (d = \sqrt{12 \times 6{\cdot}325} \times 0{\cdot}9) = (d = \sqrt{75{\cdot}9} \times 0{\cdot}9)$ $= (d = 8{\cdot}712 \times 0{\cdot}9) = (d = 7{\cdot}8408)$ or 8 ins. nearly. Suppose we say 8 ins. Then to find the breadth according to the above proportion, we multiply the 8 ins. by 0·7. Thus: $8 \times 0{\cdot}7 = 5{\cdot}6$. This determines the scantling to be $8 \times 5{\cdot}6$, for which $8 \times 5\frac{1}{2}$ or 8×6 may be used.

To find the Dimensions of Struts and Braces.

In a king-post truss:

$$a = \sqrt{S^3 \times {\cdot}0073}.$$

In a queen-post truss:

$$a = \sqrt{S^3 \times {\cdot}0023}.$$

That is to say, the sectional area (a) of the strut in a king-post truss should be equal to the square root of the cube of the span multiplied by

·0073, and in a queen-post truss the sectional area (a) should be equal to the square root of the cube of the span multiplied by ·0023.

Let the span of a king-post roof be 20 ft. We shall then have the following procedure: $(a = \sqrt{S^3 \times \cdot 0073}) = (a = \sqrt{20^3 \times \cdot 0073}) = (a = \sqrt{8{,}000 \times \cdot 0073}) = (a = \sqrt{58 \cdot 4}) = (a = 7 \cdot 6)$. The last result, being the sectional area of the strut in square inches, determines its dimensions as $3\frac{1}{2} \times 2$, $3 \times 2\frac{1}{2}$, or 4×2, the first being the usual size.

In a queen-post roof with a span of 40 ft. the scantling of the struts are determined the same way as in the preceding example; as, for instance, $(a = \sqrt{S^3 \times 0023}) = (a = \sqrt{40^3 \times \cdot 0023}) = (a = \sqrt{6{,}400 \times \cdot 0023}) = (a = \sqrt{147 \cdot 2}) = (a\ 12 \cdot 13)$. The last, being the area required, would determine the size to be $4\frac{1}{2} \times 2\frac{1}{2}$, 4×3, or $3\frac{1}{2} \times 3\frac{1}{2}$, the two first being the most usual and suitable.

Formula for determining the Scantling of Purlins.

$$d = \sqrt[4]{L^3 C},$$

C being the distance in feet the purlins are apart. The length (L) here means the distance from centre to centre of the trusses. Let this be 10 ft., and the distance apart of the purlins 6 ft. The procedure will then be as follows: $(d = \sqrt[4]{L^3 C}) = (d = \sqrt[4]{10^3 \times 6}) = (d = \sqrt[4]{1{,}000 \times 6}) = (d = \sqrt[4]{6{,}000}) = (d = \sqrt{77 \cdot 4}) = (d = 8 \cdot 8)$.

We first find the square root of 6,000, which is 77·4, and then the square root of the last number, which is 8·8, this being the fourth root nearly of 6,000. This gives the depth of the purlin as 8·8 ins. To find the thickness, multiply the depth 0·6. Thus $8{\cdot}8 \times 0{\cdot}6 = 5{\cdot}28$. This determines the scantling of the purlin to be 8½ or 9 × 5.

Formula for determining the Scantling of Common Rafters.

$$d = \frac{L}{b^{\frac{1}{3}}} \times 0{\cdot}72.$$

That is to say, the depth (d) will be equal to the length (L) divided by the cube root of the breadth ($b^{\frac{1}{3}}$), and the quotient multiplied by 0·72. The product will be the depth required.

The length (L) in this case will be the distance between any two of its adjacent supports, as, for instance, from the plate to the first purlin, or from the first to the second purlin, and so forth. Let this distance or bearing be 8 ft., and the thickness of the rafter 2 ins., the cube root of which is 1·26. We may then find the scantling thus:

$$\left(d = \frac{L}{b^{\frac{1}{3}}} \times 0{\cdot}72\right) = \left(d = \frac{8}{2^{\frac{1}{3}}} \times 0{\cdot}72\right) =$$

$$\left(d = \frac{8}{1{\cdot}26} = 0{\cdot}72\right) = (d = 6{\cdot}373 \times 0{\cdot}72) =$$

$(d = 4{\cdot}588)$. This gives a scantling of 4½ × 2 for an 8 ft. bearing.

The usual thickness of common rafters is 2

ins., in which case the depth may be found thus: $d = \cdot 571\ L$. That is: ·571 multiplied by 8 ft., the length (L) of bearing, equals 4·568. This gives the same depth as in the last example, viz. 4½ ins.

COMMON RAFTERS, 12 INS. APART FROM CENTRE TO CENTRE.*

Bearing in Feet.	Breadth in Inches.				
	1¾	2	2¼	2½	3
	Depth in Inches	Depth in Inches.	Depth in Inches.	Depth in Inches.	Depth in Inches.
5	3	2⅞	2¾		
8	4¾	4½	4⅜	4¼	4
10	6	5¾	5½	5⅜	5
12	7	6¾	6½	6⅜	6
14	8¼	8	7¾	7½	7
16	9½	9¼	8¾	8½	8
18	10½	10¼	10	9½	9
20	11¾	11½	11	10½	10

PURLINS OF NORTHERN PINE, COVERING SLATE.

Bearing in Feet.	Distance apart in Feet.			
	6	7	8	9
	Dpth ins × Brdth. ins	Dpth. ins × Brdth ins.	Dpth. ins. × Brdth ins	Dpth ins × Brdth. ins.
6	6 × 3½	6¼ × 3¾	6½ × 4	6¾ × 4¼
7	6¾ × 4	7 × 4¼	7¼ × 4½	7½ × 4½
8	7½ × 4½	7½ × 4¾	8 × 4¾	8¼ × 5
9	8¼ × 5	8½ × 5¼	8¾ × 5¼	9 × 5½
10	8¾ × 5¼	9¼ × 5½	9½ × 5¾	9¾ × 5¾
11	9½ × 5¾	9¾ × 5¾	10¼ × 6	10½ × 6¼
12	10 × 6	10½ × 6¼	10¾ × 6½	11¼ × 6¾
13	10¾ × 6½	11¼ × 6¾	11½ × 7	12 × 7¼
14	11¼ × 6¾	11¾ × 7	12¼ × 7½	12½ × 7½

* This and the two following tables are taken from Hurst's "Architectural Surveyor's Hand-Book."

TABLE OF SCANTLINGS—WOOD ROOFS.

Span in feet.	Tie Beam.	King Posts	Queen Posts	Small Queens	Principal Rafters	Straining Beam	Braces	Purlins	Common Rafters
	ins. ins	ins ins	ins. ins	ins ins	ins ins	ins ins	ins ins	ins ins	ins ins
20	9½ × 4	4 × 3	—	—	4 × 4	—	3½ × 2	8 × 4¼	3½ × 2
22	9½ × 5	5 × 3	—	—	5 × 3½	—	3¾ × 2¼	8¼ × 5	3¾ × 2
24	10½ × 5	5 × 3½	—	—	5 × 4	—	4 × 2½	8½ × 5	4 × 2
26	11½ × 5	5 × 4	—	—	5 × 4¼	—	4¼ × 2½	8½ × 5	4¼ × 2
28	11½ × 6	6 × 4	—	—	6 × 3½	—	4½ × 2¾	8¾ × 5¼	4½ × 2
30	12 × 6	6 × 4½	—	—	6 × 4	—	4¾ × 3	9 × 5½	4¾ × 2
32	10 × 4½	—	4½ × 4	—	4½ × 6¼	6¾ × 4½	3¾ × 2¼	8 × 4¾	3½ × 2
34	10 × 5	—	5 × 3½	—	5 × 6½	6¾ × 5	4 × 2½	8½ × 5	3¾ × 2
36	10½ × 5	—	5 × 4	—	5 × 6¾	7 × 5	4¼ × 2½	8½ × 5	4 × 2
38	10 × 6	—	6 × 3¾	—	6 × 6	7¼ × 6	4½ × 2½	8½ × 5	4 × 2
40	11 × 6	—	6 × 4	—	6 × 6½	8 × 6	4½ × 2½	8½ × 5	4¼ × 2
42	11½ × 6	—	6 × 4½	—	6 × 6¾	8¼ × 6	4½ × 2¾	8¾ × 5¼	4½ × 2
44	12 × 6	—	6 × 5	—	6 × 7	8½ × 6	4½ × 3	9 × 5	4¾ × 2
46	12½ × 6	—	6 × 5½	—	6 × 7¼	9 × 6	4¾ × 3	9 × 5½	5 × 2
48	11½ × 6	—	6 × 5¾	6 × 2¼	6 × 8	8¼ × 6	4½ × 2¾	8½ × 5	4 × 2
50	12 × 6	—	6 × 6¼	6 × 2½	6 × 8½	8½ × 6	4½ × 2¾	8¾ × 5	4¼ × 2
52	12 × 6½	—	6 × 6¾	6 × 2¾	6 × 8¾	8¾ × 6	4¾ × 2¾	8¾ × 5¼	4¼ × 2
54	12 × 7	—	7 × 6¼	7 × 2¼	7 × 7¾	9 × 6	4¾ × 2¾	8¾ × 5¼	4½ × 2
56	12 × 8	—	7 × 6¾	7 × 2½	7 × 8	9¼ × 6	5 × 2¾	8¾ × 5¼	4½ × 2
58	12 × 8½	—	7 × 7¼	7 × 2¾	7 × 8¼	9½ × 7	5 × 2¾	9 × 5¼	4¾ × 2
60	12 × 9	—	7½ × 7	7 × 3	7½ × 8	10 × 7	5 × 3	9 × 5½	4¾ × 2

Trusses, 10 feet apart; pitch, 27°; covering, slate; timber, northern pine.

CHAPTER V.

ROOFS OF SPECIAL CONSTRUCTION.

A FEW remarks in reference to some special kinds of roofs, which are adopted only occasionally, may not be uninteresting to the reader.

Three kinds of such roofs may be considered here, viz., the curb or mansard roof, the hammer-beam roof, and roofs having framed trusses with curved ribs, but no tie-beam.

A Curb or Mansard Roof is one in which the rafters on each side are in two separate lengths and form two different slopes, as shown in Fig. 76. One object of this form of roof is to obtain space for rooms, of which AB would be floor and CD the ceiling joist.

The first slopes, as AC and BD, are in some cases made nearly vertical, the sides being framed with a plate at bottom and top, as at A and C, and struts or braces thrown out at the partitions and cross walls, as at CE.

The ceiling joists, CD, are then laid and spiked on the top plate, by which means the two sides are

tied securely together. Another object of this kind of roof is to diminish the excessive height to which

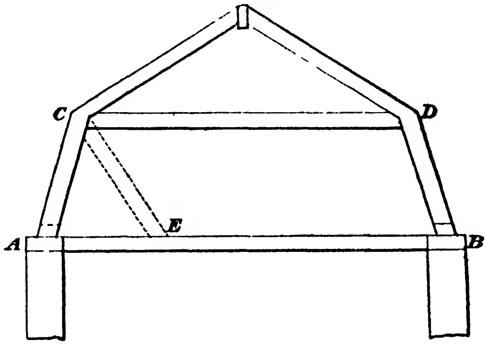

Fig 76.

the first two slopes would carry the ridge, even when set out according to the methods hereafter given.

This form of roof may be varied considerably, and many methods of describing it might be given. Two, however, must suffice here. In

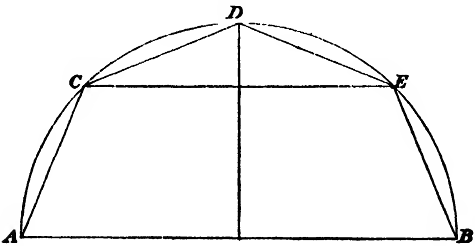

Fig 77.

Fig. 77, upon the base AB, describe the semicircle ADB, and divide it into four equal parts,

AC, CD, DE, EB; join the points of division, and the resulting demi-octagon is the profile required.

Another Method for a Curb or Mansard Roof.—In Fig. 78 describe a semicircle on the base AB, and divide its circumference into five equal parts in 1, 2, 3, 4; then the chords A1, B4, are the sides of the true roof, and 1C, 4C, those of the false roof. This last method is said to have been generally adopted for proper roofs of this description,

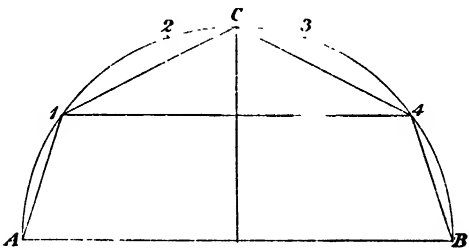

Fig 78

both on account of its simplicity and the good effect which it produces.

This roof is used for both private houses and public buildings. In the former case the sides of the rooms are made vertical and the shape of the roof and timbers hidden by lath and plaster. In the latter case, the form of the roof is seen from the inside, the principal timbers being also visible, and it therefore becomes important to

choose the form which will produce the best effect as seen from the inside of the building.

Hammer-beam Roofs.—Hammer-beams are described in Newland's "Carpenter's and Joiner's Assistant" as "a short beam attached to the foot of a principal rafter in a roof in the place of the tie-beam." Hammer-beams are used in pairs and project from the wall, but do not extend halfway across the apartment.

"The hammer-beam is generally supported by a rib rising up from a corbel below, and in its turn forms the support of another rib, constituting with that springing from the opposite hammer-beam an arch. Although occupying the place of a tie in the roofing, it does not act as a tie; it is essentially a lever, as will be obvious on an examination of Fig. 79.

"Here the inner ends of the hammer-beam AA receive the weight of the ribs springing from them, which is balanced by the pressure of principals at their outer ends."

This description will apply more particularly to the more elaborate specimens of this kind of roof which are found over some old Gothic buildings, notably that of Westminster Hall, which is one of the largest and most magnificent specimens of hammer-beam roof.

In the more common and simple examples straight timbers take the place of the curved ribs. The hammer-beam, however, performs the same office and acts and is acted upon in the same way as in the case of curved ribs like those shown in Fig.

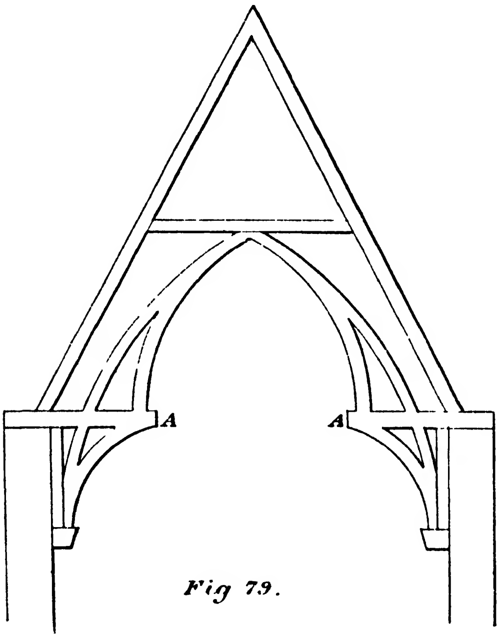

Fig 79.

79. A sketch of the more simple form is shown in Fig. 80, in which AA are the hammer-beams, BB are struts framed into the hammer-beams at their upper ends, and into the vertical wall-piece, CC, at their lower ends. The wall-pieces stand on

corbels, with their upper ends framed into the hammer-beams. The vertical struts, DD, are framed into the hammer-beams, and into the

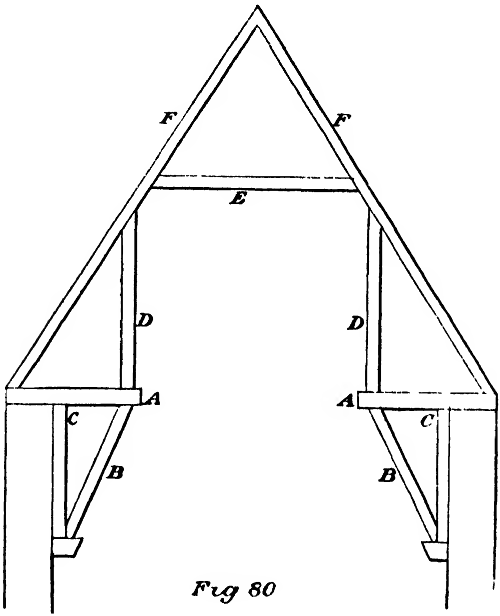

Fig 80

rafters, FF, the collar, E, also being framed into the latter.

By this method of framing a considerable amount of the thrust or weight is thrown vertically upon the walls, but not the whole of it, and unless the walls are exceptionally thick and strong, or are supported by external buttresses, the down-

ward or horizontal thrust of the rafters will always be sufficient to push them out of the perpendicular and thus force them farther apart than they should be.

Roofs having Framed Trusses with Curved Ribs, but no Tie-beam.—Fig. 81 is a sketch showing a

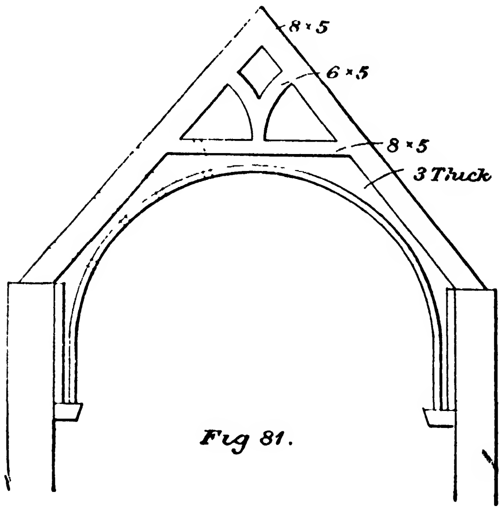

Fig 81.

principal of this kind. It was designed by an architect of eminence for a Roman Catholic chapel.

The pitch, as will be observed, is a steep one. The sizes of the timbers employed are all figured. The vertical wall-pieces stand on stone corbels well and securely built into the walls.

Being visible, the whole is wrought and moulded or chamfered, more usually the latter. The only resistance to be obtained in a principal of this description to the spreading of the rafters at their feet, and the consequent thrusting over of the walls, is by carefully framing the collar, and securing it at each end to the rafters by good straps.

The 3-in. curved ribs will also materially assist in preventing the spread of the rafters if their straight back edges are fitted closely into the grooves which are made in the collar and rafters to receive them, and the bolts are inserted so that the two may be screwed up tightly and securely together.

By these means and no other can a principal of this kind be made to retain its proper form, and even with these precautions supporting buttresses to the walls are usually employed.

CHAPTER VI.

ROOFS OF WOOD AND IRON.

A FEW of the more simple forms of roofs with iron tie-rods and king-bolts will be noticed in this chapter.

In some instances an iron king-bolt and cast-iron head for the upper ends of the rafters only are used, the wooden tie-beam being retained for various reasons. It may have a ceiling to carry, or there may be a difficulty in getting a proper abutment for the struts with an iron tie-rod.

Fig. 82 shows a king-bolt truss with a cast-iron head for the rafters. The latter is shown to an enlarged scale in Fig. 83. It may have a groove for the reception of the ridge or not, as may be considered advisable. A good abutment for the struts, and one which admits of them being placed at a suitable angle, is obtained by using a straining-sill as shown on the top of the tie-beam.

Fig. 84 shows a truss with iron tie-rod and king-bolt. The struts abut against each other,

and rest upon a stout iron plate, which rests upon the tie-rod, the latter being flattened here for

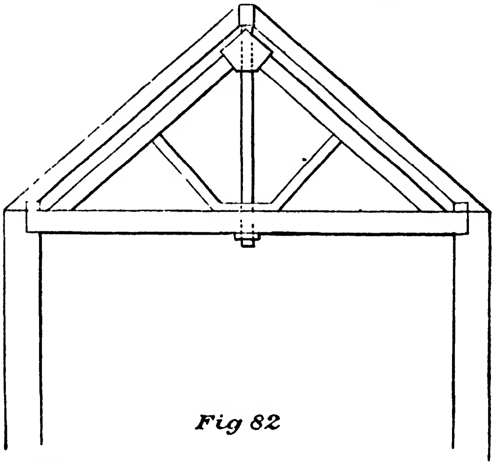

Fig 82

the purpose. The ends of the rafters should be

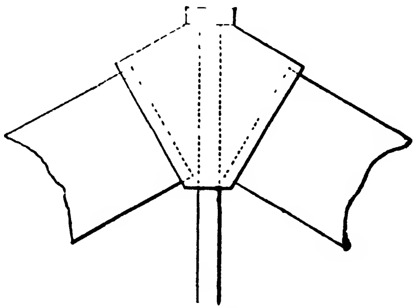

Fig 83.

cut at right angles to the direction of the tie-rod, which should have screwed ends, with nuts

and washers sufficient for drawing up and keeping them in place.

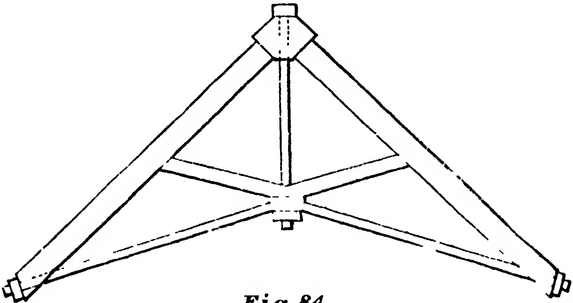

Fig 84.

Another combination truss of wood and iron is shown in Fig. 85.

Instead of struts as in the last example, a collar is framed into the rafters. The tie-rod is made to the required shape with screw-ends and nuts.

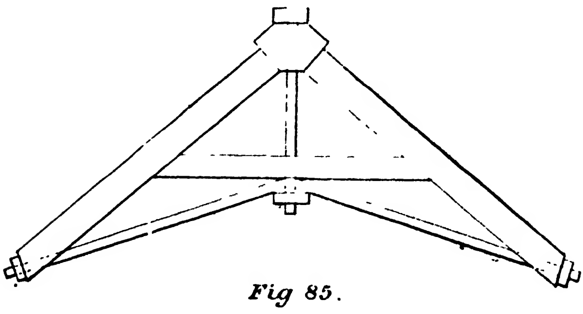

Fig 85.

The king-bolt is then passed through the collar and tie, having a screw-end and nut for tighten-

ing up as required. Trusses which are made like the two last examples will require to be drawn up to their places only, as an undue screwing up of the nuts beyond this will easily force them out of their proper form.

Other combinations of wood and iron trusses, much more elaborate and costly than the examples we have given, are also employed in special cases, but as their employment usually requires a special design and a competent designer, we shall not attempt to reproduce any of them here.

CHAPTER VII.

HIP ROOFS.

The most simple form of hip roof is that shown in Fig. 7 (page 6), which may be described as a quadrilateral pyramid.

The roof is formed by four sloping sides, each triangular in shape, and all of the same dimensions. The four arrisses formed by the meeting of the four sloping sides are the hips, and the rafter in each angle running from the eaves to the apex is a hip-rafter. The rafters which lie between the hip-rafters, and whose upper ends abut against the same, are called jack-rafters. The common rafters are those which run from the eaves to the ridge, or which are the same length as the sloping side of the roof, and which are not shortened by being abutted against the hip-rafter.

The hips should always truly bisect the angle of the building to be roofed in, whether it be a right, acute, or obtuse angle. Inattention to

this will be productive of error and unsightly workmanship.

Various methods of producing a correct result—*i.e.* of making the hip-rafter lie perpendicularly over the bisecting line of the angle on plan—are practised by different workmen, some of them very good, others not so.

It does not matter so much, however, what method is adopted so long as it is not a wasteful one either in time or material, and so long as a correct result follows. Still the method of ascertaining the required particulars in making a drawing to scale is so simple and easy of application, when working full size, that we should say there would be great advantage in adopting it *in toto.* The bevels for the common jack and hip rafters may all be found from a drawing made to scale, but for the actual lengths full-size dimensions should be resorted to.

The plan and section of a roof being given, all other requirements may be determined from them.

These requirements are the length and bevels of the common rafters, the length and bevels of the jack-rafters, the length and bevels of the hip-rafters, and the bevels for mitreing the purlins at the hip-rafters.

Before entering upon a consideration of any of

these perhaps it may be as well to describe the method of laying down the plan of a hip.

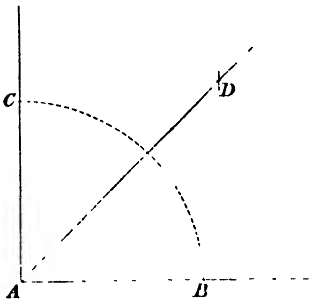

Fig 86

In Fig. 86, let BAC be the angle of a building (in this instance a right angle) which is to be covered with a hip roof. Take the angle A for centre, and with any convenient radius, as AB, describe the quadrant BC. Then take B and C for centres, and, with the same or any other convenient radius, describe arcs intersecting each other, as at D, and a line drawn from A through the intersection at D will be the central seat line or plan of the hip. This is simply bisecting the angle BAC.

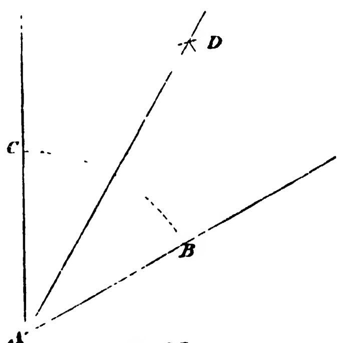

Fig 87.

The same procedure is adopted with an acute or obtuse angle, as shown in Figs. 87 and 88, in both of which the line AD is the plan

of the hip, and when the roof timbers are in their place the centre of the thickness of the hip-rafter should be perpendicularly over its plan AD.

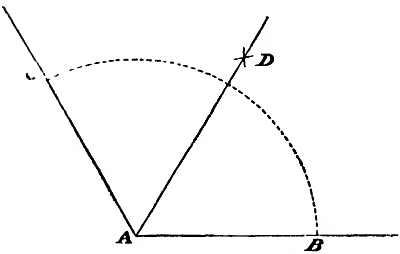

Fig 88.

The same care should be taken with valley rafters in making them lie so that they shall bisect the angle truly.

To find the Length of the Hips.—The usual method is as shown in Fig. 89, where ABCD is

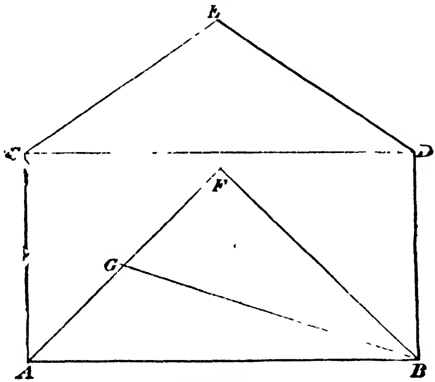

Fig 89.

the plan of one end of a right-angled hip roof. AF, BF are the seat lines on plan of the hips, and

CDE the pitch of the roof. To find the length of the hip, both of which are alike in this case, make FG equal to the height FE, and draw BG, which will be the length required.

It must not be forgotten that the plan used for taking the lengths of the hips and valleys must be a plan of the roof and not a plan of the building or plates on which the rafters rest; and

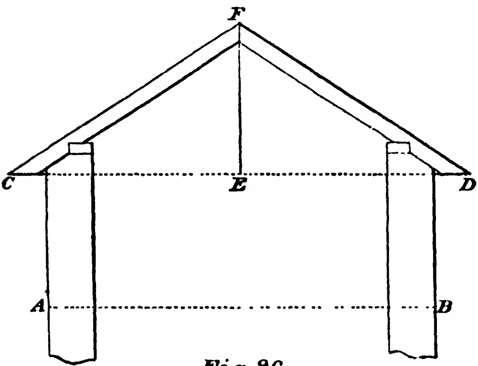

Fig 90.

also that the dimensions of this plan must include the overhanging of the eaves or projection of the rafters beyond the plates and walls.

In other words the dimensions for the plan of the roof must be equal to its extreme dimensions in section. It is therefore necessary to make a section of the roof, or determine upon the finishing of the eaves so far as the common rafters are

concerned, before proceeding to lay down the plan.

Let tne width of the building to be roofed in be AB, Fig. 90. Draw the plates and rafters to their proper position and pitch, producing the back of the rafter to cut the soffit line (which may be drawn wherever required), as shown at C and D. Join CD, and the length of this line will be the width for the plan of the roof, and EF the height for finding the length of hips and valleys.

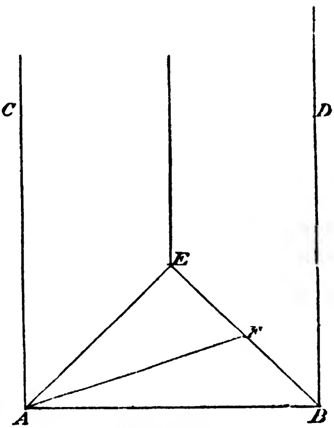

Fig 91.

To lay down the plan of one end, make AB, Fig. 91, equal to CD, Fig. 90, and draw AC and BD at right angles thereto. Draw the plan of the hips as at AE and BE, intersecting each other and the ridge at E. To find the extreme length of the hip make EF, Fig. 91, equal to the height EF, Fig. 90, and draw AF, which will be the length required.

If the end of the building is out of the square,

as at AB, Fig. 92, make the perpendicular distance between the parallel lines AC and BD equal to CD, Fig. 90. Also make EF and EG equal to the height EF, Fig. 90, and by joining AG and BF as shown, we obtain the extreme length of the hips as required.

The angle AEB in this case is a right angle, and the lengths as just found will be correct. When the angle (E) is acute or obtuse, the lengths must be found by drawing EH and EJ at right angles to BE and AE, and making them each equal to the height EF, Fig. 90. Then draw AJ and BH which will be the lengths required.

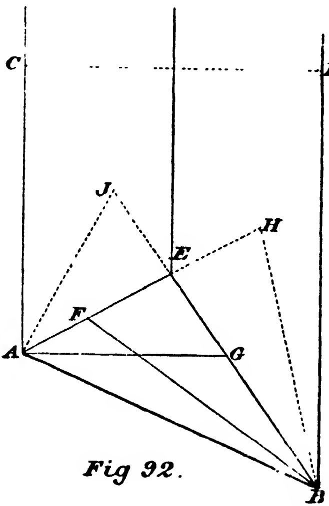

Fig 92.

To find the length of the hips in an irregular roof, the ridge to be kept level.—Let ABCD, Fig. 93, be the plan of the roof, of which CDF, Fig. 90, may be considered a section on the line FEG.

Lay down the plan of the hips at the narrow

end, CD, first, by drawing the lines, CE, DE, as directed for Figs. 87 and 88, and through the intersection at E, draw FE, GE at right angles to each side respectively. From E draw EJ, EH, parallel to the sides AD and BC respectively, cutting the plan of the hips from A and B in H and J. Draw also HJ, and the triangle EHJ will be level, from the three sides of which, and the

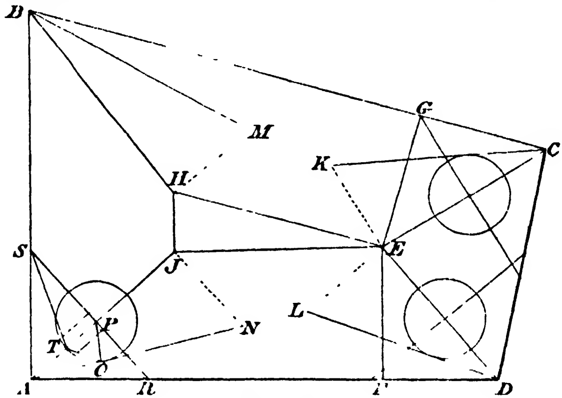

Fig 93.

point E, all the four sides of the roof will incline equally.

Draw EK, EL, HM, JN, at right angles to the plan of the hips DE, CE, AJ, BH, and make them each equal to the height of the roof EF, Fig. 90. Then draw DL, CK, AN, BM, and these last lines will give the extreme length of the four hips as required.

The lead flat will be level, thus making the common rafters all the same length. The jack-rafters will cut up against the hip-rafters on opposite sides in pairs, and both the common and jack rafters will be at right angles to the eaves of each side respectively.

Fig. 93 may be described as the plan of a truncated hip-roof. It is necessarily so with such a plan, in order that the two longest sides may be true and out of winding, and the ridge level. The consequence of dispensing with the V-shaped lead flat, and having one ridge only, and that kept level, would be that the two sides of the roof would wind, the common rafters would be of different lengths, and the two hips, AJ and BH, would be thrown out of their proper place.

If one ridge is made to do, and the sides of the roof are made true and out of winding, the hips AJ and BH would be in their proper place, but the ridge would be out of the level, and the common rafters of different lengths.

Right-angled buildings are also frequently covered with a truncated hip-roof to diminish the great height to which the rafters would otherwise run. A wide building may thus be roofed in with a snug low roof. A curb is framed to the required size, the sides of which are made parallel to the eaves line of the roof, and against this curb the

rafters abut in the same way as they would against a ridge. The curb also carries the timbers, which are given the necessary fall for carrying off the water, and on which the boarding is laid to receive the lead for the formation of the lead-flat.

The length of valleys is found in the same way as hips. In Fig. 94, let ABCDEF be the plan

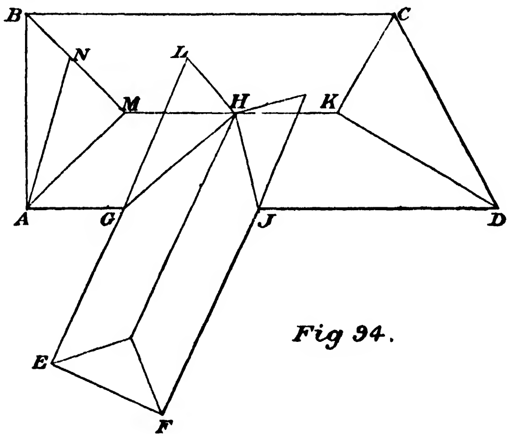

Fig 94.

of an irregular compound roof in which the ridges and eaves are required to be kept level, the building being of different widths, and let CDF, Fig. 90, be a section of either one of the roofs. Draw the plan of the ridges in the middle of the width of each roof, and from where they cut each other, as at H, draw GH and JH, which will be the plan or central seat line of the valleys. Draw

HK and HL at right angles to JH and GH, and equal to EF, Fig. 90. Then draw JK and GL, and these will be the lengths of the valleys as required.

The lengths of the hips and valleys as obtained in the foregoing diagrams are on the centre lines only, no allowance having been made for the thickness of either these or the ridge. They are the lengths of the angle or arriss which results from the meeting of the sloping sides of the roof, and that is why we term them simply hips and valleys. These lengths are sufficient for taking off quantities and other matters connected with the work of an office, but not for practical purposes.

The actual lengths of both the hip and valley rafters will be somewhat shorter than the hips and valleys as found in the preceding figures, when their thickness and that of the ridge is allowed for. This will become evident on referring to some of the figures which follow. The central seat lines of hips, valleys, and ridge should always be drawn to intersect each other, as shown in the plans already given. Then set off on each side of them half the thickness of each, as required to complete the plan.

It would be somewhat difficult, in making sketches to such a small scale as one is compelled

to adopt in a work of this description, to show all the required particulars clearly, by drawing all the parts to their proper dimensions. It will therefore be necessary to exaggerate some part of the diagrams above others, and this we shall do whenever it may be deemed advisable, perhaps largely in some instances.

The foot of the hip-rafter stands on what is

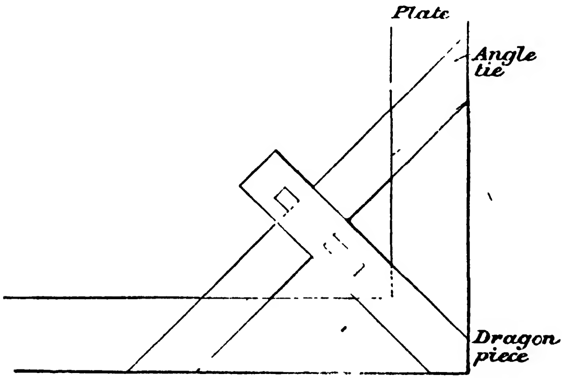

Fig 95.

termed a dragon-piece, which, at its innermost end, is framed into an angle tie. These are shown in plan at Fig. 95.

The dragon-piece is best kept up above the plate somewhat, and should have a shallow mortice into which the lower end of the hip-rafter is fitted to prevent its sliding outwards.

To find the backing of a hip-rafter, i.e. to bevel its top edge so that each half of its thickness shall be in the same plane as the adjacent sides of the roof. In AN, Fig. 93, take any point O, and draw OP at right angles to AN, cutting AJ in P. Through P draw SPR at right angles to AJ, cutting the sides AB and AD in S and R. Make PT equal to PO, and draw TS and TR. Then the angle STR will give the backing of the hip-rafter, and when bevelled as shown, each half of its thickness will be in the same plane as the adjacent sides of the roof.

The backing may be found also with somewhat less trouble as follows. In the seat line AJ take any point P, and draw SPR at right angles to the seat line AJ. Then take P for centre and describe a circle touching the hip AN as shown, and from where this circle cuts AJ, as at T, draw TS and TR, which gives the angle T for the backing of the hip-rafter as before. As the same method applies to acute and obtuse angles, as shown at the end CD of the same figure, there will be no necessity to repeat the description.

To find the mould for the hip-rafter.—Let DEF, Fig. 96, be a section of the roof, with the plate shown in position as at E. From this draw the plan of one end of the roof and the centre lines, as

AC, BC, CF. On each side of CF, set off half the thickness of the ridge, cutting the centre of the hip-rafter in H and G, and draw GH, which will be the end of the ridge. Then set off half the thickness of the hip-rafters on each side of AC and BC, as JL, KL, MN, OP, and NGLHP

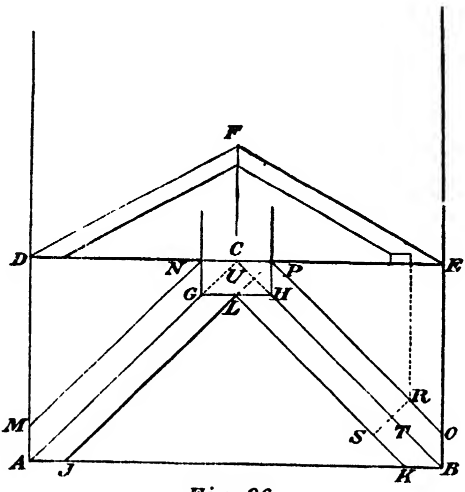

Fig 96.

shows how the hip-rafters should be cut against the square end of the ridge.

Draw the line for the plan of the plate, cutting the hip-rafter as at RS (the angle of the plates should be cut off square to the plan of the hip as shown, RS being equal to the thickness of the hip-rafter).

In Fig. 97, make ABCD equal to CUTB, Fig. 96. Draw AE at right angles to AD and make it equal to CF, Fig. 96, and draw DE.

From B draw BF parallel to AE, and DF will be the length of the hip-rafter, and DFB will give the bevel for the side or vertical cuts to fit against the ridge. Parallel to DF draw the width of the hip-rafter downwards, cutting the lower end to fit into the dragon-piece as shown, and DCFG will be the mould for the hip-rafter as required.

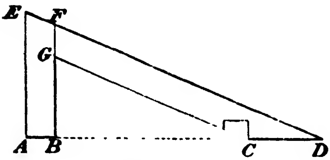

Fig 97

To find the lengths and bevels of the jack-rafters, also the bevels of the hip-rafters.—To do this the simplest and best method is to find the covering for that part of the roof which shall include the hip and jack rafters, as, for instance, that for the hipped end of ABC, Fig. 96, as follows. In Fig. 98, draw a straight line and make the divisions ABCD equal to AJKB, Fig. 96. Then with DE, Fig. 97, as radius, and A and D, Fig. 98, as centres, describe arcs intersecting at E, and draw AE, DE, and the triangle ADE will show the shape and size of covering required for the hipped end of the roof, whose plan is ABC,

Fig. 96. From the points B and C, Fig. 98, draw BF and CF parallel to AE and DE, and the triangle BCF will show the shape and size of the covering required in the clear of the hip-rafters, the plan of which is JKL, Fig. 96. Through F, Fig. 98, draw HG parallel to the eaves line AD, and the angle BFH or CFG will give the bevel to which the hip-rafter should be

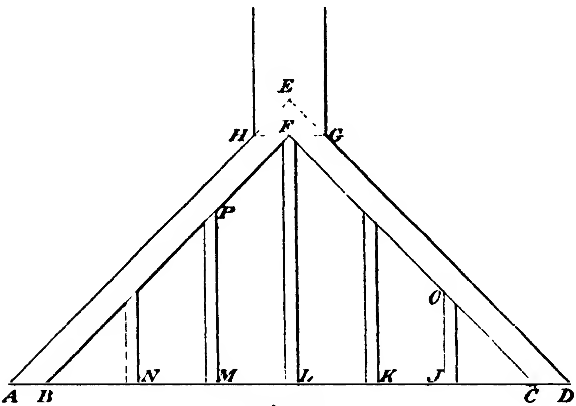

Fig 98.

cut through half its thickness on each side of the centre. If then the top end is cut to this bevel from each side, and to the vertical bevel as given by the angle DFG, Fig. 97, it will fit against the end of the ridge, as shown in plan at LHP, Fig. 96.

Draw the jack-rafters wherever they are required, as at JKLMN, Fig. 98, at right angles

to the eaves line AD, and the lengths will be JO, MP, and so forth. The bevel across their thickness will be the angle JOC or MPB. The vertical bevel of all jack-rafters will be the same as that of the common ones, which in Fig. 96 is given by the angle EFC, the length of the rafter extending from the point E to the ridge.

To find the foregoing lengths and bevels when the end of the building is not square.—The same method of procedure as that just described for a square, building will apply when the building is not square, as at AB, Fig. 92, with the difference that the lengths of both hip-rafters must be found.

Let ABC, Fig. 99, be a section of the roof, and ADEB the plan of one end. Draw the plan of the hips and the centre of the ridge as at DF, EF, FC, intersecting each other at F. On each side of FC set off half the thickness of the ridge, and draw lines as shown cutting the plan of the hips in G and H, and draw GH. Also set off half the thickness of the hip-rafters on each side of the centre lines and draw JO, KO, LP, MN. The end of the ridge will then be cut as at GH, and the hip-rafters will cut up against it as at NGOHP. The backing of the hip-rafters is found as previously described for Fig. 93. The length of the common rafters will be from B to the

ridge, and the bevel for the vertical cut will be the angle BCF, which will also be the bevel for the vertical cuts of all the jack-rafters against the hip-rafters.

Draw the plan lines for the outside of the plate

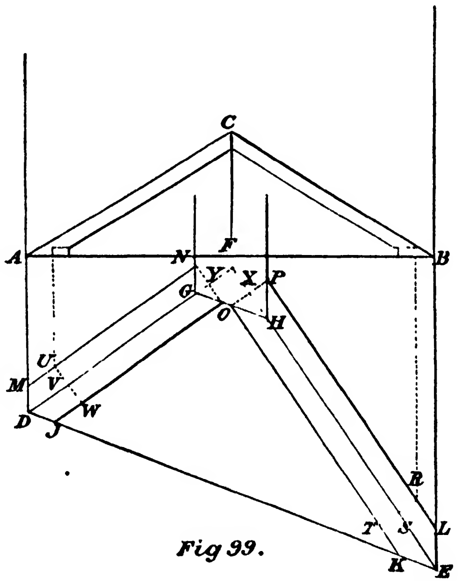

Fig 99.

as shown by the dotted lines, and from where these cut LP and MN, as at R and U, draw RST and UVW at right angles to the plan of the hip-rafter. Draw also the dotted lines OP and ON cutting the centre of the hip-rafters at X and Y.

To find the mould for the hip-rafter on the

right draw the line AD, Fig. 100, and make the divisions ABCD equal to FXSE, Fig. 99. Draw AE, Fig. 100, at right angles to AD, and make it equal to FC, Fig. 99. Then join the points DE, and draw BF parallel to AE, and DF will be the length of the hip-rafter. Parallel to DF set off the width downwards, and DFCG will be the mould as required.

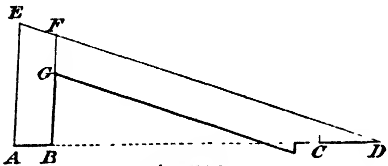

Fig 100.

To find the mould for the hip-rafter on the left, make the divisions ABCD, Fig. 101, equal to DVYF, Fig. 99. Draw DE, Fig. 101, square to AD, and CF parallel to DE.

Join the points AE, and AF will be the length of the hip-rafter. Set off the width as before, and ABGF will be the mould as required.

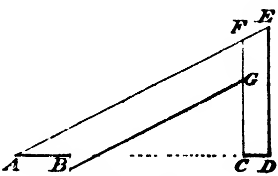

Fig 101.

To find the lengths and bevels of the jack-rafters, and the bevels for the upper ends of the hip-rafters.

In Fig. 102, make the divisions ABCD equal to DJKE, Fig 99.

Take D, Fig. 102, for centre and describe an

arc at E, with radius DE, Fig. 100; also take A, Fig. 102, for centre and with radius AE, Fig. 101, describe an arc intersecting the former one at E, and draw AE, DE.

Then the triangle ADE will give the shape and size of covering required for the hipped end

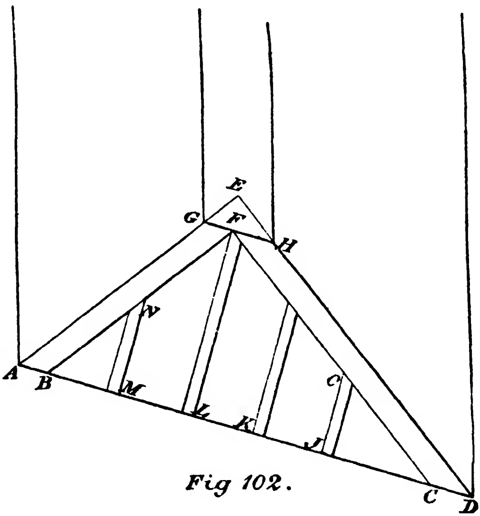

Fig 102.

of the roof, the plan of which is DEF, Fig. 99. From the points B and C, Fig. 102, draw BF and CF parallel to AE and DE, and BCF will give the shape and size of covering required in the clear of the hip-rafters, the plan of which is JKO, Fig. 99.

Draw GH, Fig. 102, through F, parallel to the eaves line AD, and CFH will be the bevel for the long hip-rafter, and BFG will be the bevel for the short one.

The upper ends of the hip-rafters should be cut to these bevels on the backed edge from each outside to the centre, and to the vertical bevels as given by the angles AED, Fig. 101, and DEA, Fig. 100. They will then fit against the end of the ridge, as shown at NGOHP on the plan, Fig. 99.

Fill in the jack-rafters, wherever they are required, by drawing them at right angles to the eaves line AD, Fig. 102, as shown at JKLM, and the bevel for the thickness of all those against the long hip-rafter will be the angle JOC, and that for all those against the short hip-rafter will be the angle MNB, while their extreme lengths will be JO, MN, LF and so forth.

The same lengths and bevels will apply to the jack-rafters on both sides of each hip-rafter respectively.

The same method will apply for finding the lengths and bevels for jack-rafters which come against a valley rafter. Suppose it is required to find the lengths and bevels of the jack-rafters in the side of the roof, as shown in plan at AGMH, Fig. 94, and of which CDF, Fig. 90, is a section. First find the hip and valley, as at AN and GL,

Fig. 94. Then to find the covering for the side AGMH, draw two parallel lines, as AB, CD, Fig. 103, at a perpendicular distance apart equal to CF or DF, Fig. 90. Then take A, Fig. 103, for centre, and for radius the length of the hip AN, Fig. 94, and describe an arc cutting the line CD at C, and draw AC.

Make the lines AB and CD, Fig. 103, equal to AG and MH, Fig. 94 (that is, the length of the

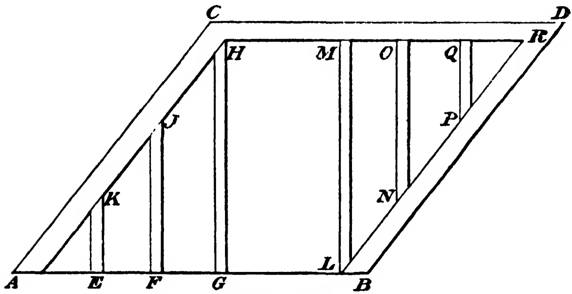

Fig 103

eaves and ridge respectively), and draw BD, which should be equal to the length of the valley GL, Fig. 94. Then ABCD, Fig. 103, will be the shape and size of covering required from the eaves to the centre of the ridge, and from the centre of the hip-rafter to the centre of the valley rafter for the side of the roof, as shown in plan at AGMH, Fig. 94.

Parallel to AC, CD, and BD, Fig. 103, set off

half the thickness of the hip-rafter, ridge, and valley rafter in the same way as for Figs. 98 and 102. Then fill in the jack-rafters by drawing them at right angles to the eaves line AB, as at EK, FJ, GH.

These lines will give the length, and the angle GHA the bevel, for the thickness of the jack-rafters against the hip-rafter. Also LM, NO, PQ will give the length on the back, and the angle MLR the bevel for the thickness of the jack-rafters against the valley rafter.

The extra length required for the jack-rafters, LM, NO, and PQ, beyond that shown in the figure, is easily ascertained from the bevel for the vertical cut, which will be the same as that for the upper ends of the common rafters.

To find the bevels for mitreing the purlins at the hip-rafters.

Purlins are made to occupy one of two positions. The top edge is either made horizontal, and the sides vertical, or the top edge is placed to the slope of the rafters and the sides at right angles to the same. When the sides are vertical, the side cut for the mitre would be vertical also, *i.e.* square to the top and bottom edges, while the bevel for the mitre across the thickness should correspond to the angle of the plan. As for

instance, in a right angle the bevel would require to be set to an angle of 45°, or to ABC, Fig. 96. For an obtuse or acute angle as at D and E, Fig. 99, the angle DEF will give the bevel for the acute, and the angle EDF the bevel for the obtuse.

This position of the purlin of course presents no difficulty whatever at the mitre.

There is very little more difficulty in finding the required bevels if the edges are placed to the slope of the rafters. When they are made to occupy this position, which is the most usual one, the bevels for the cuts across the edges may always be taken from the development of the covering, as in Figs. 98 and 102. Thus, if the plan of the roof is square, the bevel should be set to the angle ADE or DAE, Fig. 98, for the cross cuts.

When the plan is out of square, as in Fig. 99, the bevel for the cross cuts in the acute angle should be set to the angle ADE, Fig. 102, and for that in the obtuse angle, to the angle DAE.

The down or side bevels are found as shown in Fig. 104. There is really no necessity for drawing a separate diagram, as the bevels can be obtained from the plans, as in Figs. 96 and 99. An extra figure is shown here for the purpose of making the matter as clear as possible.

Let ABCD, Fig. 104, be the plan of a roof

with one end square and the other not, as shown. Draw the plan of the hips as at AE, DE, BF, and CF. Draw the slope of the common rafters as

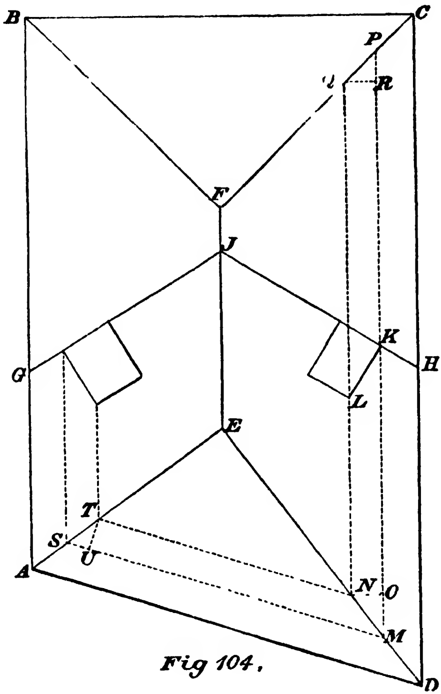

Fig 104.

GJ, HJ, and let KL be the depth of the purlin and at right angles to the slope of the roof.

From the angles K and L draw the horizontal lines KM, LN, parallel to DC, cutting the plan of the hip in the acute angle in M and N.

Make NO square to LN, and MO will be the distance the down or side cut of the purlin should be out of square, the top, of course, being the longest.

In Fig. 105 let the distance between the parallel lines AE and BD be equal to the depth of the purlin with AB square to AE, and let the distance BC equal the distance MO, Fig. 104. Draw the line AC, and the angle EAC will give the bevel for the down or side cut as required. Three different bevels are required for the purlins of a roof like this one. One as already found for the acute angle, one for the obtuse, and one for each of the square angles.

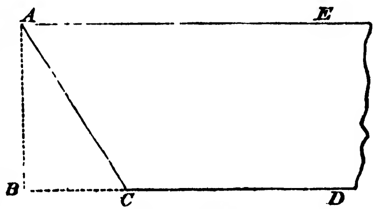

Fig 105.

They are all found in the same way as that just described.

For the square angles, produce the lines MK and NL to cut the seat of the hip in P and Q. From Q draw QR, square to QL, and RP will be the distance the down cut should be out of square for the purlins at this end. For the obtuse angle from the points M and N draw NT and MS parallel

to AD, cutting the seat of the hip in S and T. From T draw TU square to NT as before, and SU will give the distance the down cut of the purlin should be out of square for this angle.

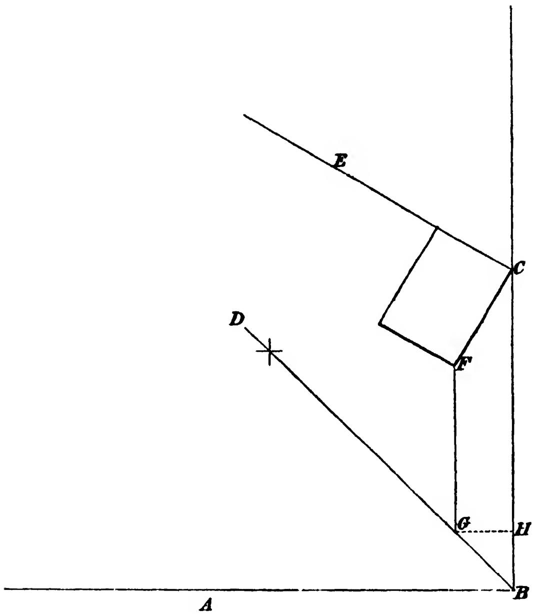

Fig 106.

It is by no means necessary, however, to lay down the plan of the whole roof to get the required bevels, or to place the purlin in its proper position under the rafter. They may be obtained as shown in Fig. 106. Thus, let ABC be the

plan of one angle of the roof, BD the plan of the hip, EC the slope of the rafter, and CF the depth of the purlin drawn at right angles to the pitch of the roof, and the angle C to the eaves line as shown. From the lower angle of the purlin as at F, draw FG parallel to the eaves line BC, and from G, the point where FG cuts the plan of the hip BD, draw GH at right angles to BC, and BH will give the distance the purlin will require to be out of square for the down cut.

The same description will apply in every particular to an acute or obtuse angle.

When the bevel for the down cut is found as in Fig. 106, it will be best to draw the purlin full size.

This can be done easily on a board 11 ins. or even 9 ins. wide, when the angle of the building and the slope of the common rafters are known.

Another method* of finding the bevels for the purlins is as follows :—

In Fig. 107 let ABC be the plan of one angle of the building, BD the plan of the hip, BEF the inclination or pitch of the common rafters, and EFGH the purlin. From the angles EFG of the purlin, draw EJ, FK, and GL parallel to AB, producing FK indefinitely as shown

* From J. Wilson's "Carpentry and Joinery."

to Q, and on the right set off the depth as at KM, and draw MD parallel to FK.

On the left set off the thickness as at KN,

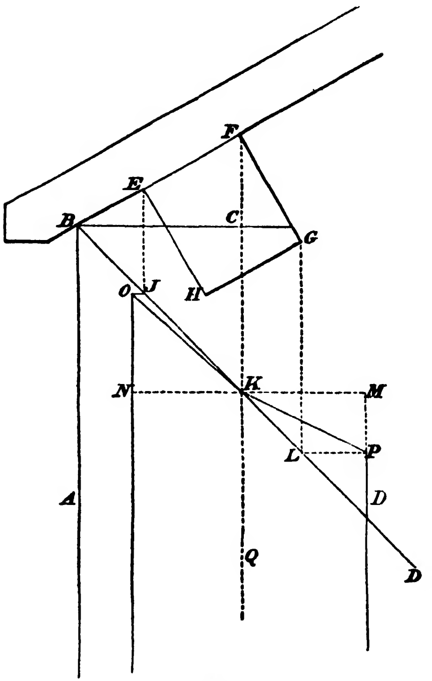

Fig 107.

and draw NO parallel to FK, thus making KM equal to FG, and KN equal to EF. From the points where the perpendiculars from E and G cut the plan of the hip, as at J and L, square over

the lines JO and LP, and from where these cut the lines MD and NO, as at O and P, draw KP and KO. Then the angle QKP will give the bevel for the down or side cut, and the angle NOK will give the bevel for the cut across the edge or thickness.

The same process will be necessary to obtain the bevels for an acute or obtuse angle.

The same method will apply for finding the bevels of the purlins when they are employed in connection with curved ribs or rafters, as shown in Fig. 108. Let ABC be the plan of one angle of a building, BD the plan of the hip, and EFG and HJK the purlins placed to the curve of the rib as shown. From the upper angles of these let fall the perpendiculars GL, FM, EN, KO, JP, and HQ, cutting the plan of the hip as before.

Then draw the widths of the sides and edges respectively of the purlins parallel to the perpendicular from F and J, as in the previous example, and the bevels may be obtained in exactly the same way as there described.

As in the preceding example of straight rafters, the same method will be applicable for finding the bevels when the angle of the building is acute or obtuse.

It will be observed that the plane of the covering for the roof as developed in the foregoing

diagrams is immediately on the back of the common rafters, and that the bevel for the edges

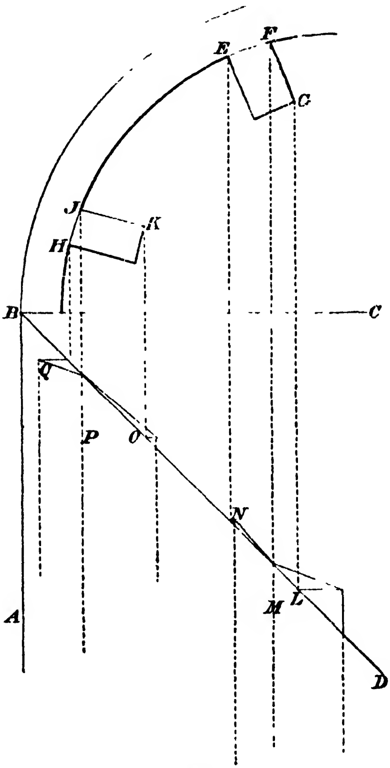

Fig 108.

of any timbers which lie in that plane or in a plane parallel and in close proximity to it may be taken from such development.

Thus, the edges of purlins, when placed in the position shown in Fig. 104, the edges of jack-rafters, and the edges of half the thickness of the hip-rafters all lie in this plane, or parallel to it as in the case of purlins, and the development will give any required bevel for any of them.

The practical man will see the advantage of this, and the ease and simplicity with which the covering for the side of any roof may be laid down.

As before observed, all required bevels may be obtained from a drawing made to scale. We may supplement that, and say that if a tolerably large scale is practicable the lengths of all jack-rafters, common rafters, and hip-rafters may also be taken from it accurately enough for all practical purposes.

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